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Herring acoustic surveys for 2002 in NAFO Divisions 4WX.

Relevés acoustiques du hareng réalisés en 2002 dans les divisions 4VWX de l'OPANO.

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Abstract

Automated acoustic recording systems deployed on commercial fishing vessels were used to document the distribution and abundance of Atlantic herring in NAFO Division 4VWX. As in previous years the data were collected during both industry vessel surveys and fishing excursions. Regularly scheduled surveys, at approximately 2-week intervals were conducted on the main spawning components in accordance with the planned program. The spawning stock biomass for each component was estimated by summing the results of surveys undertaken over the spawning season at scheduled intervals (i.e., >10 day). In 2002, 3 surveys were conducted in Scots Bay, 2 on Trinity Ledge and 2 on German Bank following established protocol and providing good coverage of the spawning areas consistent with previous years. Additional data were from 1 fishing night in Scots Bay and 3 fishing nights on German Bank to estimate the total SSB of the individual spawning components. Survey coverage of Trinity Ledge was extremely poor and is unlikely to represent the SSB. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 141,000t, 8,100t, and 393,000t for a total SSB of 542,000t in the traditional survey areas. A single survey around Seal Island documented 1,240t of spawning fish and no data were available for Browns Bank. The total SSB for the Bay of Fundy/SW Nova Scotia component of the 4WX herring complex in 2002 spawning season was estimated to be 543,000t. This represents a significant increase over the previous year and it removed much of the concern over the large decline in SSB for German Bank. Biomass estimates for surveys of the coastal Nova Scotia spawning components were significantly higher in 2002. No large aggregations of herring were observed on the offshore Scotian Shelf and acoustic surveys were conducted in the Bras d'Or lakes.

Résumé

On a utilisé des appareils automatisés d'enregistrement acoustique montés sur des bateaux de pêche commerciale pour documenter la distribution et l'abondance du hareng atlantique dans les divisions 4VWX de l'OPANO. Comme par les années passées, les données ont été recueillies dans le cadre de relevés effectués par l'industrie et d'excursions de pêche. Des relevés des principales composantes de reproducteurs ont été effectués environ toutes les deux semaines selon le programme planifié. On a estimé la biomasse de reproducteurs pour chaque composante en additionnant les résultats des relevés faits pendant l'époque de la fraie à intervalles réguliers (soit > 10 jours). En 2002, trois relevés ont été effectués dans la baie Scots, deux sur la chaussée Trinity et deux sur le banc German selon le protocole établi, ce qui a donné une bonne couverture des frayères, comme les années précédentes. D'autres données ont été recueillies lors d'une nuit de pêche dans la baie Scots et de trois nuits de pêche sur le banc German pour estimer la BSR totale de chaque composante de reproducteurs. Comme la chaussée Trinity a été extrêmement mal couverte lors des relevés, il est peu probable que les données obtenues représentent la BSR. Les estimations de la biomasse pour la baie Scots, la chaussée Trinity et le banc German la situe à environ 141 000 t, 8 100 t et 393 000 t respectivement, ce qui donne une BSR totale de 542 000 t dans les secteurs traditionnellement recensés. L'unique relevé effectué alentour de l'île Seal a permis d'établir la présence de 1 240 t de reproducteurs. Aucune donnée n'est disponible pour le banc de Browns. On a estimé que la BSR totale de la composante de reproducteurs de la baie de Fundy et du sud-ouest de la Nouvelle-Écosse du complexe de 4VWX atteignait 543 000 t pendant l'époque de la fraie de 2002. Ceci représente une augmentation importante par rapport à l'année précédente, ce qui a calmé les inquiétudes que suscitait la baisse marquée de la BSR sur le banc German. Les estimations de la biomasse des composantes de reproducteurs des eaux côtières de la Nouvelle-Écosse issues des relevés étaient nettement meilleures en 2002. Aucun grand banc de hareng n'a été observé dans les eaux hauturières du plateau néo-écossais. Des relevés acoustiques ont aussi été réalisés dans le lac Bras d'Or.

Introduction:

Evaluation of the 4WX herring stock status has relied on industry conducted acoustic surveys of spawning grounds since 1998 (Melvin *et al.* 1998, Stephenson *et al.* 1998). Each year commercial fishing vessels equipped with calibrated acoustic logging systems undertake both scheduled and unscheduled surveys of herring spawning grounds. The data obtained from these systems are then analyzed, in near real-time when necessary, and used as input for the "survey, assess, then fish" protocol, and/or incorporated into the annual assessment process. Prior to the development and implementation of the automatic acoustic systems, biomass estimates were qualitative and relied on the experience of the observer to estimate the amount of fish from mapping surveys (Melvin et al., 2002).

The practice of using commercial fishing vessels to evaluate spawning stock biomass (SSB) was initially implemented to provide additional protection of individual spawning components within a global TAC during a period (1994-95) of declining biomass. The original qualitative approach, commonly referred to as the "survey, assess, then fish" protocol, continues today, but uses a quantitative acoustic methodology with a standard survey design (Melvin and Power, 1999; Melvin *et al*, 2001, Power *et al.*, 2001) to estimate biomass. The herring industry has also recognized the value and contribution the surveys make in evaluation of stock status. As such, they have entered into a three year Joint Project Agreement (JPA) that defines the level of effort and support to be provided by DFO and the fishing industry.

Since 1999 improvements have been made in the areas of survey design and in the standardization of survey coverage to a point where they can be considered comparable from year to year (Melvin and Power, 1999; Melvin *et al*, 2001; Power *et al*, 2002).

The purpose of this document is to report and summarize the 4VWX stock assessment related survey data collected during the 2002 fishing and survey season.

Methods:

Acoustic and mapping surveys using commercial fishing vessels have been employed to estimate the spawning stock biomass of individual components within the stock complex for the past 5 years. The methods and procedures are well established and documented in previous research documents (Melvin et al., 2001, 2002). This section provides only a general overview of the approach. A detailed description of the methodology and analytical approach is presented in Appendix A.

Data collected and used to estimate the spawning stock biomass (SSB) during the 2002 fishing season were obtained during both standard fishing operations and structured (i.e. organized) surveys. Structured surveys were either acoustic or mapping surveys (Melvin *et. al.*, 2001). In 2002 no major changes from previous years were made to the established protocol for either acoustic or mapping surveys. The 14 surveys scheduled for 2002 were completed on or near the tentative dates scheduled. Table 1 summarizes the number of structured surveys undertaken for each area.

In general, surveys were conducted in accordance with the protocol established in Melvin and Power (1999). Furthermore, there was an improvement in the survey design in situations when only a single aggregation of fish was surveyed. In most cases, vessel captains established a series of parallel transects to document the fish, rather than the unorganized search pattern common in fishing operations. The trend of moving away from mapping surveys toward standardized and scheduled acoustic surveys continued. However, there was a greater reliance in 2002 on fishing night data for several areas than in 2001. For German Bank fishing night data were used to estimate the abundance of herring during the early and late part of the spawning season. When structured surveys were undertaken there was a vast improvement in the compliance to protocol and good coverage of the survey area. There were no deviations from the standard survey practices in 2002.

Length/Weight Relationship:

Prior to 2001 the weight in the target strength (TS) equation (Appendix A) was estimated using a length/weight relationship developed from monthly data. In other words, length and weight data from all areas for a given month were used to calculate a length/weight relationship. This relationship was then used to estimate the weight of a fish for a given length. In 2001 the procedure was changed slightly to improve the estimate of weight. Given the extensive nature of our sampling it was possible to obtain a significant number of detailed samples (length/weight data) within a 10 -day window, 5 days either side each of the surveys (Table 2). The same procedure was used in 2002.

Acoustic Systems:

In 2002, acoustic data were collected using automated logging systems aboard commercial fishing vessels during both standard fishing excursions and structured surveys. The systems, which were activated whenever the captain wished to document observations, automatically saved all data to the system's hard drive. The data were downloaded at regular intervals to either a removable hard-drive or tape prior to archiving and analysis. Eight automated acoustic logging systems were deployed on commercial fishing vessels. Systems were installed and calibrated aboard the purse seining vessels *Margaret Elizabeth, Island Pride, Dual*

Venture, Leroy & Barry and the *Secord* and on the inshore gillnet boats, *Crystal K* and the *Attaboy*. A portable system used in previous years for multi-vessel deployment was fixed to the purse seiner *Lady Melissa* in 2002.

Structured Surveys:

Structured surveys are defined as those surveys that follow the standard protocol described by Melvin and Power (1999). Under this protocol, surveys cover a series of randomly selected transects within a pre-defined area. The number of transects depends upon the number of vessels involved. Acoustic recording vessels are distributed throughout the survey area to provide representative coverage. The surveys are also conducted at regular intervals throughout the spawning season. In 2001 DFO and the Herring Science Council signed a 3-year Joint Project agreement that defined the minimum number of structured surveys to be conducted on each spawning ground. These surveys, which are generally scheduled at two week intervals, play an important role in our understanding and perception of the 4WX herring stock. However, sufficient flexibility was built into the process to allow for schedule changes, which increase the number of surveys, and to allow for the investigation of areas of interest or uncertainty. Structured surveys were conducted on each of the major, and several of the minor, spawning grounds within 4WX, as well as non-spawning aggregations (Figure 1), in accordance with the terms of the JPA.

Fishing Excursions:

Fishing nights are defined as those occasions when acoustic data are collected by fishing vessels equipped with automated acoustic logging systems activated during the search phase of nightly fishing excursions. These data, which do not follow any formal survey design, provide information on the distribution and abundance of herring during non survey nights. The data have also been used to document large spawning aggregations not included in a survey and/or as a substitute for a survey in the event no other information is available. Our approach to the activation practice has changed since we started the program. During the early stages fishing captains would turn their system on when they reached the fishing ground and off once they deployed their fishing gear. For the last 3 years, the majority of vessels have activated their systems only when they believed there was something worth recording. This has greatly reduced the amount of time required for archiving, editing and analyzing. Analyses of acoustic data from non-survey nights increased due to the provision of technical support for the program in 2002. Data from 4 fishing nights were used in the estimate of German Bank SSB for 2002.

Results:

The 4WX herring spawning stock biomass in 2002 was estimated from industry coordinated structured acoustic and mapping surveys of individual spawning components within the stock complex. These surveys form the foundation for evaluation of the stock status. In the absence of a structured survey, acoustic data from fishing excursions were used to estimate component SSB for a given night. The following provides a summary of the 2002 observations and SSB estimates for each of the main spawning components and stocks. The number of surveys scheduled, the number actually completed and the number of fishing nights used in the biomass estimate are summarized in Table 1.

Bay of Fundy/SWNS:

Biological Sampling for Maturity:

The timing of surveys in relation to the residence time of spawning groups on the spawning grounds is an issue discussed at length each year. To investigate this further, in 2002 herring maturity data were obtained from two sources: 'Roe Analysis Data Sheets' from Scotia Garden Seafoods and the standard biological sampling program conducted by staff at the St. Andrews Biological Station (SABS).

Data, in the form of 'Roe Analysis Sheets', were made available by Scotia Garden Seafoods on a daily basis, often with multiple samples from different boats. These were random samples of 50 to 100 fish with the males and females separated and the individual gonads weighed into categories for use by the plant. From these data we were able to determine overall percent weight of mature, immature, and spent females as well as percent weight of the male gonads. The plant classification system must not be confused with the standardized scientific scale of 1 to 8.

The SABS biological samples provided data on individual fish for length, weight, sex, maturity stage, gonad weight and age. For comparsion with the industry data the maturity stages regrouped such that, stage 1 (immature) to 5 (mature/hard roe) were combined as immature, stage 6 (ripe and running) was designated as mature and stages 7 (spent) and 8 (recovering) were combined as spent. It is standard procedure not to weigh stage 6 (ripe and running fish) as these weights can be highly variable depending on the amount of roe that has been lost and so are not representative of the full roe sac. A modification to the SABS lab procedures should be considered for the future in order to make more exact comparison with industry maturity samples. SABS samples were combined for female fish by day and percent numbers by the three categories determined.

'Roe Analysis Sheets' for 22 Scots Bay samples were provided by Scotia Garden Seafoods for 7 days from Aug. 6^{th}-12^{th}, 2002. Roe fish were present in the samples throughout this period and the percent of roe to overall weight exceeded

50%. There were peaks in the percent roe around August 10th and 12th (Figure 2, top panel). SABS maturity data were available for 17 samples (631 fish) from July 26 to September 4th. These data showed 4 separate peaks in percent roe (Figure 2, middle panel). The combined data averaged by day from both sources showed that survey timing closely corresponded to peaks in higher percentages of mature female roe herring (Figure 2, bottom panel).

'Roe Analysis Sheets' for 41 German Bank samples were provided by Scotia Garden Seafoods for 27 days from August 14th to October 12th, 2002. There were roe fish throughout this period with the percent of roe to overall weight exceeding 50% and with several peaks and dips (Figure 3, top panel). SABS maturity data were available for 29 samples (892 fish) from August 2nd to October 9th and these also showed several peaks (Figure 3, middle panel). The combined data averaged by day from both surveys showed that survey timing corresponded to breaks in roe maturity for female herring (Figure 3, bottom panel).

Scots Bay:

During the 2002 spawning season four surveys were conducted in Scots Bay between July 28th and September 2nd (Table 3). Although the surveys began later than in most years of the series (the first survey was on July 16th in 2001), the last survey was completed approximately 2 weeks later than normal. Some spawning herring may have been missed given the presence of spent fish in the July 28th samples. However, mature spawning herring dominated (96% stages 5 & 6) samples collected on the 2nd and 4th of September. The remaining 4% were spent fish. Overall the Scots Bays surveys were well conducted and provided good coverage of the spawning area. Data from a number of fishing nights in Scots Bay were analyzed, but were not used in the estimate of SSB (Table 4).

The first Scots Bay survey was conducted on the night of July 28th and involved 11 commercial purse seiners with 3 acoustic logging systems. The survey, which began off Margaretsville, followed pre-defined northeast transects for approximately 35km up the bay (Figure 4). Eleven transects were completed by the vessels, all south of the Isle de Haute. Survey coverage was generally good and the transects were assumed to reflect the distribution of spawning herring, although 3 of the shoreward transects were cut short. Boundaries for the survey area were determined using information from all vessels. The coverage area for the survey was 325km^2. Target strength (TS= - 35.76) was estimated from mean length of fish (27.8cm) sampled during the survey night and a length-weight relationship of detailed samples collected from Scots Bay during the survey period (Table 2). Length frequency data used to estimate target strength are presented in Figure 5 and indicated adult fish sizes only. Ninety-seven percent of the herring sampled contained ripe or ripe/running fish (Stage 5-6), consistent with fish within 1 week of spawning. The remaining fish were in spent condition suggesting that some spawning had already occurred. Estimates of fish density, based on distance weighted mean Sa of the transects, ranged from 0.015 to 0.184 kg/m^2. The

observed SSB in Scots Bay on the night July 28, 2002 was estimated to be 41,200t (Table 3).

The second Scots Bay survey was conducted by 14 purse seiners, 4 with acoustic recording systems, on August 11th, 2002. Unfortunately, the recording system on one vessel encountered a technical malfunction and the data could not be used for biomass estimation. Survey coverage of the spawning grounds was excellent and encompassed an area of 400km^2 (Figure 6). The data clearly demonstrated that the majority of herring were concentrated in the southern portion of the survey grid and close to the Nova Scotia shore. The target strength estimate of –35.42 was based on the mean length of herring (27.5cm) sampled from catches in Scots Bay on the night of the survey and the weight /length relation in Table 2. Again the size distribution of fish indicated spawning adults (Figure 7). Examination of the gonads from detailed samples confirmed adult herring with the majority of fish in stage 5 or 6. A few spent fish were also found in the samples. Transect densities were lower than the first survey and ranged from 0.005 to 0.089 kg/m^2. Based on a distance weighted mean Sa of –49.45, the spawning biomass observed in Scots Bay on the August 11th was 15,824t (Table 3).

A third survey involving 7 vessels, two with acoustic recording systems, was undertaken in Scots Bay on August 21st, 2002. The survey, which was more limited in coverage (275 km^2), concentrated on the southern, near shore waters of the spawning area where the majority of herring were observed in previous surveys (Figure 8). No herring were observed in the northern portion of the survey area. Mean length (27.3cm) from the length frequency data (Figure 9) and a weight-length relationship from samples collected during the survey time (Table 2) were used to estimate the target strength (TS= -35.40). All herring sampled were of adult size and detailed samples contained only fish with gonads in an advanced stage (stages 5 and 6) of development or spent. Transect fish concentrations ranged from 0.050 to 0.325 kg/m^2 and when weighted for distance resulted in a mean Sa of –40.765. The total SSB for August 21st was 79,938t (Table 3).

The final Scots Bay survey was conducted on September 2nd, 2002 by 6 vessels and one acoustic recording system. The vessels undertook a broad scale survey of the spawning grounds covering an area of 195 km^2 and then concentrated their effort on an aggregation of herring in 1.3 km^2 (Figure 10). For analysis, the data were divided into two separate sections, the large area and the small aggregation. Examination of the gonads from detailed samples collected after the survey indicated that all fish were mature and the majority (97%) of fish were at stage 6. A few stage 5 and spent fish were also observed. The length frequency from 4 samples displayed a distribution consistent with adult fish (Figure 11). Biomass estimates for both sections were made separately, but based on a common mean length of 26.42 cm and a TS of –35.26 (Table 2). The total SSB observed in Scots Bay on the night of September 2 for both sections combined was 3,975t (Table 3).

The 2002 Scots Bay SSB estimate from all four surveys was approximately 141,00t (Table 3). Although, the SSB is slightly lower than the 2001 estimate of 163,900t, it is well above the 1998-2000 average of 92,500t. This represents the fourth year of surveys with good coverage of this spawning component.

Trinity Ledge:

Over the past two years the surveying of spawning herring on Trinity Ledge has become less organized and may not fully reflect the abundance of fish. Prior to 2001, surveys used multiple vessels (10-20) and the portable acoustic logging system to cover most of the potential spawning area (Melvin and Power, 1999). In 2001 an automated acoustic logging system was fixed to a single vessel for surveying. Since then the vessel has had a tendency to concentrate on only a small area with aggregations of fish and structured multi-vessel surveys seem to have been abandoned. Mapping surveys undertaken by multiple vessels also concentrated their effort on small areas. Consequently, biomass estimates for Trinity Ledge in 2002 should be considered poor and unrepresentative as only a very small portion of the spawning ground was covered. Obtaining a representative sample of fish size has also been a problem given the fishery uses size-selective gear (gillnets). A 4 panel multi-mesh gillnet built in 2001 specifically to collect a representative sample of herring was not used in 2002. As such, all biomass estimates are based on the standard TS estimate of –35.5 adjusted for a frequency of 120kHz to –35.96. More effort is needed to coordinate surveys, to increase coverage, and to collect good samples during the spawning season.

In addition to the poor coverage, surveying on Trinity Ledge in 2002 was late, beginning on September 2. Given that the traditional spawning season extends from August 15th to September 15th , it is likely that the early spawning group was missed. Both the number of nights data were available and the maximum area (0.6 km^2) covered on any a given night decreased (Table 5).

Biomass estimates on Trinity Ledge were made from acoustic data collected on 2 of the 3 nights of data, September 2nd and September 13th (Table 5, Figures 12 and 13). The data from September 8th and 9th were not used in the estimate given that insufficient time (10-14 days) had elapsed since the date of the previous data collection. In both cases the SSB was based on the standard TS adjusted for frequency. The total SSB for Trinity Ledge spawning component in 2002 was 8,100t (Table 5).

German Bank:

The 2002 estimate of spawning stock biomass for the German Bank spawning component was based on a mixture of data collected during fishing nights and structured surveys (Table 6). Structured surveys were organized around the traditional spawning period whilst the fishing night data were used to reflect the early and late portion of spawning. Data from a number of fishing nights were

analyzed, but not used in the estimate of SSB (Table 7). The number of structured surveys on German Bank decreased from 6 in 2001 to 3 in 2002. The primary reason for the lack of structured surveys on German Bank during the latter part of September and early October was that the majority of the fleet had used their quota for the 2002 fishing season or were directing their effort toward non-roe fish in another fishing area. This resulted in a greater reliance on fishing night data for the last part of the spawning season. Turnover time of herring on German Bank has always been a concern of both the fishing industry and DFO. Based on detailed analysis of available gonad maturity data and the elapsed time between surveys, all dates selected for inclusion of the 2002 SSB estimate were independent. Immature/small herring were observed in only the first and last survey nights and represented a very small percent of the sampled fish (5% and 0.3%). No adjustment to the biomass was made to account for the presence of small fish (Figure 14).

Acoustic data collected from the fishing night of August 11th were used for the first estimate of SSB for 2002. The herring industry has always reported spawning herring on German Bank several weeks before the first structured survey. This year an effort was made to collect data from the early spawning group. Several fishing nights before August 11th were examined, however based on the available gonad data it was considered too early in the season for spawning herring (Table 7). The majority of samples contained a large proportion of small or maturing fish. Although, no detailed gonad data were available for August 11, the presence of almost 100% stage 6 herring on August 14, strongly suggests that the adult fish observed on the 11th were likely ripe and running. The information from a single vessel was divided into 3 separate areas (Figure 15) for biomass estimates and the biomass summed to determine the quantity for the night. Area 1 was a 3.61 km^2 dense aggregation of herring where the vessel concentrated it effort. Area 2 was larger (27.0 km^2) and area 3 covered a small aggregation (0.70km^2) where several runs through the fish were made. The same input parameters were used for all areas (Mean length, 27.75, TS= -35.65). Density estimates ranged from 0.122 for area 2 to 0.6378 kg/m2 for area 3. On August 11, 2002 the SSB estimate on German Bank was 2,866t, 2,090t in area 1, 225t in area 2 and 446t in area 3 (Table 6).

The first structured survey of German Bank occurred on August 26th, 2002. Ten vessels with five acoustic logging systems undertook the survey of German Bank and the area around Seal Island. The elapsed time between the first and second survey was 15 days. The vessels provided excellent coverage of the spawning grounds, surveying an area of 450 km^2 (Figure 16). Unfortunately, one recorder had technical problems and the data were unusable. It was argued by industry that the vessel had run a transect through the densest part of the fish. Consequently, the densest transect from another vessel was substituted for the defective transect. Length measurements were obtained from three samples (450 fish) which demonstrated a normal distribution with a mean length of 28.04 cm, and a few small fish (Figure 17). However, examination of the gonad stages from the

detailed sample showed all herring in stages 5/6, with the majority in stage 6. Target strength was estimated from the length frequency and the SSB estimated using all transects within the survey area. Mean transect density ranged from 0.002 to 0.850 kg/m^2 from the acoustic recordings after weighting for transect length. The SSB was estimated to be 117,673t (Table 6).

The third survey of German Bank was undertaken on September 10, 2002 and involved 8 vessels, 5 with acoustic recorders. Six of the vessels concentrated on the German Bank grid while the other two searched the Seal Island area for spawning herring (Figure 18). The survey, which was extremely well organized, covered an area of 375km^2. Unfortunately, the GPS unit on one of the recording systems became disconnected and although data were collected, no position information was available in the file. It was however possible to reconstruct the vessel track from the detailed notes on time and position taken during the survey. Transect data from all vessels were used in the estimate of SSB. Length frequency samples showed the presence of adult size fish, mean length 27.45 cm and the detailed samples indicate that all fish were mature (Figure 19). Based on a TS of -35.37 and a weighted mean Sa of –42.11, the SSB was estimated to be 79,410t (Table 6). Transect densities ranged from 0.09 to 0.45 kg/m^2.

Additional surveys were scheduled for German Bank in 2002, but none were conducted due in part to many of the vessels having running out of quota as the season end approached and to the targeting of non-spawning fish. However, there were a number of fishing nights on German Bank when vessels with recording systems provided information from which biomass estimates could be determined in a limited area. The first fishing night considered for estimating the total SSB was September 19, when two vessels, the *Secord* and the *Leroy & Barry* , encountered a large aggregation of herring and took the time to run several transects through the fish (Figure 20). Although, only 9 days had elapsed since the previous survey, there was sufficient evidence to indicate that a turn-over had occurred and that a new group of fish were being surveyed. All fish sampled on the 19th were of adult size (mean length = 27.3cm) (Figure 21) and in detailed samples the fish were all stage 6 (ripe and running). Thus, based on a TS of –35.28, a survey area of 35.0 km^2, and a mean Sa of –28.16 the SSB observed by the fishing vessels was 181,264t. Biomass density from the 17 transects ranged from 0.84 to 19.72 kg/m^2.

Two additional fishing nights were incorporated into the southwest Nova Scotia/Bay of Fundy SSB: September 29th and October 8th. In both cases sufficient time had elapsed and gonad data, although sparse during the latter part of the season, indicated the presence of ripe and running herring on German Bank for the fishing nights. On the night of September 29th, a single vessel documented two small groups that combined encompassed a total area of 0.35 km^2 (Figure 22). The length frequency data indicated adult fish (Figure 23). Based on a mean length of 26.58 cm and a TS of –35.15 the estimated biomass was 3,623t. On October 8 two vessels encountered two independent schools of spawning herring on German Bank (Figure 24). Again length frequency samples showed adult fish

sizes (Figure 25) and that gonad samples were ripe and running. The biomass of each school was estimated separately and then combined for an estimate of minimum SSB. Based on a mean length of 26.78cm, the input parameters in Table 2 and an area of 14.0 km^2 the biomass estimate was 8,285t.

In summary, the 2002 spawning stock biomass for German Bank was estimated to be 393,121t. The SSB is based on estimates of biomass from the fishing nights of August 11, September 19, September 29, and October 8 and structured surveys on August 26 and September 10 (Table 6). Traditionally, biomass estimates from surveys not separated by a 10-14 day interval were not considered as part of the cumulative total. On only one occasion in 2002 did the elapsed time between estimates not meet this criteria – 9 days between September 10^{th} and 19^{th} , however, based on roe content and gonad information there is significant evidence that a turn-over of spawning herring occurred between the two dates.

Spectacle Buoy:

Traditionally a spring fishery that harvests roe fish during a short period in June has occurred in the vicinity Spectacle Buoy. However, in the fall of 2001 a large aggregation of reproductively mature herring was observed on September 23^{rd} just west of the area where the spring fishery occurred. Both the spring and fall SSB estimates were included in the Bay of Fundy/Southwest Nova Scotia abundance estimates. No surveys of this area were undertaken in 2002.

Seal Island:

For several years concern has been expressed about the absence of spawning herring in the vicinity of Seal Island. In 2002 the area around Seal Island was surveyed as part of the German Bank program (Figures 16 and 18). Spawning herring were observed on two occasions, August 26 and September 10. A biomass estimate was determined for only the former night as quantities were extremely small for the latter. Based on a survey area of 275km^2 and the input parameters for German Bank the biomass estimate was 1,236t (Table 8).

Browns Bank :

No surveys were undertaken on Brown's Bank in 2002.

Summary Bay of Fundy/SW Nova:

Over the past 6 years biomass estimates determined from acoustic surveys have been used to evaluate the status of the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex. During this time the approach for estimating SSB has evolved from a heavy reliance on distribution and abundance estimates from fishing excursions with a 10 day minimum elapsed time, to structured surveys scheduled at two week intervals. In the absence of survey data

fishing excursion data were substituted. Regular monitoring of the gonad development from both industry and DFO sampling provided evidence that a turn-over in spawning fish had occurred between each survey, thus minimizing the potential for double counting from one survey to the next. The total observed biomass for the complex was obtained by summing the SSB estimate for each spawning ground.

In 2002 the total SSB for the Bay of Fundy/ Southwest Nova Scotia spawning grounds was estimated to be 543,457t, an increase of over 7% from the previous year (Table 9). However, when the SSB of just the traditional spawning areas (i.e., Scots Bay, Trinity Ledge, and German Bank) was examined the increase was approximately 18%. The SSB for Scots Bay and Trinity Ledge were down slightly, but the estimate of spawning biomass on German Bank increased by over 200,000t and back to quantities observed before 2001. The low biomass and poor surveying of Trinity Ledge is of some concern. No fish from Browns Bank are included in the estimate of SSB and only 1,236t were observed around Seal Island.

Nova Scotia Coastal Spawning Component:

The shallow inshore waters of the bays and inlets along the Atlantic coast of Nova Scotia support a number of herring spawning populations. Several documents describe reports, at one time or another, of coastal spawning in 4VWX. Our knowledge of these relatively small coastal populations is limited to a few areas where there are active commercial fisheries for roe on spawning grounds in the fall of the year. The traditional bait fishery occurs in the spring/summer of the year. In 2002, commercial roe fisheries were conducted in three areas of the Nova Scotia coastal stock component; Port Mouton/Little Hope, Jeddore/Eastern Passage and Glace Bay. Surveys of the SSB were undertaken using both the mapping and the structured acoustic survey approach, and varied depending upon the area. The results for each spawning area are presented below.

Little Hope:

Adherence to survey protocol for the spawning grounds near Little Hope/Port Mouton improved in 2002. Instead of the typical small area covered by a single vessel, multiple vessels, including one with acoustic recording system, were involved and covered a broad area. However, effort by the recording vessel was concentrated on the aggregations of fish and the analysis involved separation of the schools and the general area covered. In addition, the actual organization of the surveys and timing required a great deal of effort. Although acoustic data were collected on several nights in late September (Table 10), the first organized survey used to estimate SSB occurred on the night of September 29th. The survey, which involved 42 gillnet vessels, covered an area of more than 350km^2, documented fish in four schools and thinly scattered throughout the survey area (Figure 26). The initial biomass estimate of 18,500t was based on the mapping approach. Once

the acoustic data were available and analyzed the SSB for September 29th was revised to 13,522t. This estimate is based on the biomass from four independent schools of herring and the amount of herring in the total survey area (Table 10). The standard target strength of –35.96 was used to estimate the biomass as the only sample available from the area were from gillnets.

The second survey occurred on October 8, 2002 and involved 15 vessels. Again, the single recording vessel limited its effort to three concentrations of herring, each of which was analyzed separately (Figure 27). The size of the individual schools ranged from 2.5 km^2 in the southwest to 14.34km^2 in the northeast. The total coverage area for the survey was approximately 272 km^2 (Table 10). Unfortunately, although a variable mesh gillnet was purchased in 2001 to collect a representative sample of herring, it was not used in 2002. As a result, biomass estimates were based on the standard target strength of -35.96 (adjusted for frequency). The SSB observed during this survey was 42,493t obtained from individual estimates of each school (Table 10). The total 2002 SSB estimate for Little Hope from the October 8th and September 29th surveys was 56,015t.

Eastern Shore:

Acoustic and mapping surveys in the Eastern Shore/Jeddore area were coordinated by the Eastern Shore Fishermen's Protective Association. Acoustic data were collected on several nights throughout the fishing season, however only those nights which contained significant amounts of herring were analyzed in detail (Table 11). The 2002 SSB of 41,455t was based on data from one survey and one fishing night. The first was a mapping survey, conducted on September 19th, which provided an estimate of 16,600t in 103 km^2 (Figure 28). A survey conducted on October 3rd concentrated on a single aggregation of herring. The biomass estimate was 24,855t based on the standard TS of -35.96 in an area of 2.32 km^2 (Table 11).

Glace Bay:

Data from the Glace Bay fishery was limited and difficult to obtain in 2002. A single mapping survey involving 3 vessels was undertaken on the night of October 10th and covered an area of 40 km^2. No length frequency samples were available. The biomass from this survey was 7,700t (Table 12, Figure 29).

Bras d'Or Lakes:

In 2002 no acoustic surveys were conducted in the Bras d'Or Lakes to document the abundance of spawning herring due to the absence of an acoustic recording system in the area. The last mapping survey was conducted in 2000 and documented only 70t. Biological data are being collected and are reported elsewhere (Power et al., 2003).

Offshore Scotian Shelf Component:

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf diminished in 2002. Acoustic recorders were activated on a few occasions but insufficient quantities of fish were observed to warrant analysis. Consequently, no acoustic biomass estimates were available from the Scotian Shelf in 2002. The fall herring survey (Oct 22-Nov2), which covered a large number of the outer banks, documented very little fish (Figure 30). The largest aggregation of herring was observed on the "Patch" and no herring were captured in any fishing set southeast of the Halifax, excluding the Patch.

Chebucto Head (January 2001):

Since 1998, DFO and the herring industry have undertaken acoustic surveys of a large over-wintering aggregation of herring just off Chebucto Head, N.S. The purpose of the acoustic survey has been to estimate the abundance of herring and to investigate the movement of these mixed spawning origin fish through tagging. In 2003 a single vessel undertook an exploratory survey of the area on January 20th. The vessel found only a small group of herring just off Chebucto Head. No sampling or tagging occurred in 2003. The biomass of the small school of herring was estimate using a standard TS to be only 794t (Table 13). No other herring were observed in the area. It has been suggested that the winter aggregation was early and may have been present in December.

Discussion:

The 2002 spawning stock biomass for the Bay Fundy/Southwest Nova Scotia component of the 4WX herring stock complex was determined primarily from industry based surveys of the 3 major spawning components: Scots Bay, Trinity Ledge, and German Bank. No structured surveys were conducted outside the main spawning areas, except around Seal Island where less than 2,000t were observed. As well, no fishing night data were included in the SSB estimate except the few nights from German Bank at the beginning and end of the spawning season. Unlike 2001 no spawning aggregations of herring were documented in the vicinity of Spectacle Buoy or on Brown Bank in 2002 due to the absence of fishing activity in both areas. This is the sixth season of surveying and the forth year biomass estimates from industry based surveys have played a significant role in the evaluation of the 4WX herring stock abundance. As in previous years, there is a possibility that spawning fish were outside coverage area for any given survey and the potential for the series of scheduled surveys to miss a wave(s) of spawners using a 10-14 day interval between surveys on any given spawning ground. Consequently, the results must be considered an estimate of minimum SSB. Increased effort was also put into the documentation of spawning waves through the monitoring of changes in composition of mature herring.

In general, the majority of acoustic surveys in the Bay of Fundy/Southwest Nova Scotia in 2002 were well organized and provided good coverage of the spawning grounds. Unlike 2001, the surveys completed the assigned transects and automated recording was distributed throughout the fleet. The real deficiency in 2002 was the absence of structured surveys during late September/early October on German Bank. In these cases, fishing night estimates were substituted to determine biomass. Coverage of Trinity Ledge was again poor and the spawning stock biomass is unlikely to be representative of the amount of fish spawning around the Ledge. There was also an absence of surveys, and consequently biomass estimates, from Spectacle Buoy and Browns Bank

The observed SSB in Scots Bay in 2002 decreased slightly (22,000t) from the previous year, however, this SSB is the second highest observed in the last 5 years and it is well above the 40,000t observed in 2000. Sufficient time (10-14 days) had also elapsed between surveys and coverage was excellent. Spawning fish were observed later, into early September, then in other years. Consequently, the biomass observed on the four survey nights were added to provide an SSB of 141,000t for the component.

There were problems with surveying Trinity Ledge again this year. Although two nights of surveys were undertaken by the gillnet fleet, they were poorly organized and covered only a small portion of the spawning grounds. The multi-mesh gillnet, built to provide samples from gillnet surveys, was not used and so the standard TS of -35.96 had to be used to convert the acoustic signal to biomass. The 2002 SSB of 8,100t was based on estimates from September 2nd and September 13th which covered a maximum area of 0.6 km^2. This represented the area of a single school of fish. Even the vessels participating in the mapping strayed only a short distance from the aggregation. Consequently the biomass is unlikely to represent the entire Trinity Ledge spawning component due to the large area not included in the survey. Yet, based on the information provided by the fleet, it must be assumed that this small amount of observed herring is the 2002 SSB. Trinity Ledge once supported a large spawning component within 4WX stock complex. As such given the fact that the observed biomass has declined in 2002, any fishing on Trinity Ledge must strictly adhere to the "survey, assess, then fish" protocol during the 2003 spawning season. This means that no fishing should occur until sufficient quantities of herring are observed to allow for potential removals.

In the 2001 assessment of German Bank serious concern was expressed about the large decline in observed SSB. A number of possible reasons were put forward for the observations including missing fish during the surveys and incomplete survey coverage. The fishing industry's view was that the acoustically documented biomass did not reflect the abundance of herring observed just before or after the surveys. The survey program in 2002 began earlier and extended into October. Coverage and timing of structured surveys was excellent, however, a greater reliance was place on fishing night data for the early and late periods of the spawning season due to the lack of quota and the targeting of non-spawning

herring. As such, a large portion of the potential spawning ground was not surveyed during the fishing excursions. Based on evidence found in the variation of the proportion of stage 6 fish in landings, and the elapsed time between surveys dates, all surveys were considered independent as it appeared that a turnover of fish had occurred. The 2002 German Bank SSB estimate of 392,121t was based on a combination of structured surveys and fishing nights. This SSB represents a significant increase (>200,000t) from the 2001 estimate and removes much of the concern expressed last year. An increase in the number of structured surveys is needed to encompass the entire spawning season.

The SSB of the Bay of Fundy/ SW Nova Scotia component of the 4WX stock complex increased from 2001. The total observed SSB was 543,457t. The key differences between 2001 and 2002 are that there is a significant increase in the abundance of herring on German Bank and that virtually no data from spawning areas beyond the three main components contribute to the estimate of overall SSB. A decrease in SSB was observed on Trinity Ledge and in Scots Bay. In the former case there is a great deal of uncertainty regarding abundance due to the poor surveying effort. Improvements are needed in the survey coverage of Trinity Ledge. Scots Bay exhibits only a slight decline and the estimate is the second highest in 5 years.

Biomass estimates for the Nova Scotia coastal spawning component of the 4WX stock complex included acoustic survey data from Little Hope/Port Mouton and the Jeddore/Eastern Passage area. In both areas there was a substantial (more than doubling) increase in the observed SSB and in the amount of fishing effort (Table 14). Surveying of the Eastern Passage/Jeddore area was undertaken as required. The Little Hope/Port Mouton fishery was closed until a survey documented a sufficient quantity of herring. There was also some difficulty in organizing the surveys. It is recommended that more effort go into the organization and implementation of surveys in the Little Hope/Port Mouton area in 2003. A single mapping survey in the vicinity of Glace Bay showed approximately 7,700t of spawning herring. No biomass estimates were made for the Bras d'Or Lakes. There is a strong need to improve our knowledge of these herring spawning areas. The large winter aggregation off Chebucto Head was not found in 2002.

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Table 1. Summary of the number of scheduled herring spawning ground surveys for 2002, the number undertaken and the number of fishing nights used to estimate minimum spawning stock biomass in the 4WX stock complex. Note the number in ( ) refers to the number of fishing nights for which data were analyzed.

Spawning Ground	Surveys Scheduled	Surveys Completed	Fishing Nights
Scots Bay	3	4	0 (6)
Trinity Ledge	3	2	0 (3)
German Bank	4	2	4 (13)
Eastern Passage	1	2	
Port Mouton	1	2	

Table 2. Summary of fish sampled, length/weight relationship, target strength estimate of samples, and target strengthestimate for a 28cm herring using the length/weight equation by location date and survey.

Date	Location	Number Samples	Number Fish	Mean Len (cm)	Mean Weight (gm)	Slope	Intercept	Target Strength	Wt 28cm Fish (gm)	TS 28cm Fish
28-Jul	Scots Bay	7	1033	27.87	189.0	3.37	-2.59	-35.76	192.3	-35.80
11-Aug	Scots Bay	4	507	27.45	169.6	3.42	-2.69	-35.42	181.4	-35.54
21-Aug	Scots Bay	2	241	27.32	167.2	3.33	-2.57	-35.40	181.4	-35.54
02-Sep	Scots Bay	4	420	26.42	150.3	3.05	-2.17	-35.23	179.4	-35.50
02-Sep	Trinity Ledge#							-35.96*		
13-Sep	Trinity Ledge#							-35.96*		
11-Aug	German Bank	3	312	27.75	182.6	3.16	-2.30	-35.65	187.9	-35.69
26-Aug	German Bank	3	450	28.04	187.8	3.26	-2.45	-35.68	186.9	-35.67
10-Sep	German Bank	7	833	27.45	167.4	3.19	-2.36	-35.37	178.3	-35.47
19-Sep	German Bank	8	1026	26.26	161.2	3.17	-2.35	-35.28	176.3	-35.42
29-Sep	German Bank	4	550	26.57	149.3	3.18	-2.36	-31.15	176.3	-35.42
08-Oct	German Bank	2	-314	26.67	145.5	3.12	-2.78	-35.24	169.2	-35.24

* TS adjust by -0.46 dB to account for difference in acoustic signal from 120 kHz system.
# Gillnet sample – used standard TS of –35.5 (adjusted for frequency when necessary).

Table 3. Summary of the 2002 Scots Bay spawning ground acoustic survey data and associated biomass estimates for each time period. The total SSB for the spawning component is obtained by summing the biomass estimates. Target strength was estimated for length frequency samples collected from the area on the night of the survey. Total SSB is rounded to nearest 100t.

Location/ Type	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Scots Bay								
Survey	July 28	325	-44.740	0.127	27.87	-35.76	41,211	6,062
Survey	Aug 11	400	-49.448	0.040	27.45	-35.42	15,824	10,231
Survey	Aug 21	275	-40.765	0.290	27.32	-35.40	79,938	17,001
Fishing	Sep 02	1.3	-30.902	2.709	26.42	-35.26	3,522	886
Survey	Sep 02	195	-61.568	0.002	26.42	-35.26	453	243
						Total	141,000	

Table 4. Summary of acoustic biomass estimates of SSB in Scots Bay from selected fishing nights.

Location/ Type	Date	Vessel	Area (km^2)	Target Strength	Mean Sa (dB)/m^2	Density (kg)/m2	Biomass (t)
Scots Bay							
Fishing	23-Jul	SC	6.00	-35.71	-30.25	3.52	21,071
Fishing	26-Jul	LB	34.00	-35.80	-35.05	1.19	40,417
Fishing	5-Aug	LB, SC	10.50	-35.64	-34.48	1.31	13,704
Fishing	8-Aug	LB, SC	8.00	-35.42	-29.60	3.89	29,629
Fishing	13-Aug	SC	2.00	-35.42	-30.04	3.46	6,908
Fishing	14-Aug	SC	5.50	-35.42	-31.86	2.27	12,479

Table 5. Summary of the 2002 Trinity Ledge acoustic survey results and SSB biomass estimate. Acoustic surveys covered only a small portion of the spawning ground. Total SSB estimated from September 2 and September 13 surveys.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Trinity Ledge								
	02-Sep*	0.47	-27.36	7.244	-	-35.96	3,405	357
	08-Sep*	0.35	-29.81	4.127	-	-35.96	2,472	2,050
	13-Sep*	0.60	-27.02	7.819	-	-35.96	4,691	440
						Total	8,100	

*TS adjusted for difference in 120kHz

Table 6. Summary of the 2002 German Bank spawning ground acoustic survey results and SSB biomass estimates from surveys.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
German Bank								
Fishing	Aug 11	31	-46.03	0.09	27.75	-35.65	2,866	1,083
Survey	Aug 26	450	-41.51	0.26	28.04	-35.68	117,673	18,636
Survey	Sept 10	375	-42.11	0.21	27.45	-35.37	79,410	7,274
Fishing	Sept 19	35	-28.16	5.18	27.23	-35.28	181,264	40,070
Fishing	Sept 29	0.35	-25.58	9.06	26.57	-35.15	3,623	970
Fishing	Oct 8	14	-37.60	0.58	26.67	-35.24	8,285	2,832
						Total SSB	393,121	

Table 7. Summary of the 2002 herring biomass estimates observed during fishing on German Bank. The vessel names are Dual Venture (DV), Island Pride II (IP), Lady Melissa (LM), Leroy & Barry (LB). Only estimates from September 29 and October 8th were used in the 2002 German Bank SSB estimates.

Date	Fishing Vessel (s)	Area (km^2)	TS (dB/kg)	Wt. Mean S_a ($/m^2$)	Biomass Density (kg/m^2)	Biomass (tons)
1-Aug-02	DV	1.50	-35.6504	-34.7690	1.2250	1,838
4-Aug-02	DV	5.56	-35.6504	-35.1770	1.1152	6,200
6-Aug-02	DV	19.00	-35.6504	-38.6040	0.5066	9,625
11-Aug-02	IP	45.00	-35.6504	-45.3610	0.1069	4,810
21-Aug-02	DV,LB	5.00	-35.6806	-28.6480	5.0496	25,248
4-Sep-02	DV.LB	6.00	-35.3700	-30.5360	3.0411	18,247
5-Sep-02	DV,LB	4.00	-35.3700	-32.7060	1.8451	7,381
17-Sep-02	LM	3.00	-35.2175	-28.3620	4.8478	14,544
18-Sep-02	IP	0.75	-35.2175	-21.7130	22.4104	16,808
29-Sep-02	IP	0.40	-35.1515	-25.2650	9.7383	3,623
7-Oct-02	IP	0.75	-35.1709	-34.4100	1.1915	894
8-Oct-02	IP	2.25	-35.1709	-36.1410	0.8127	1,829
8-Oct-02	LB	2.00	-35.1709	-37.9320	0.5380	3,230
8-Oct-02	Total IP/LB					5,059
11-Oct-02	LB	4.10	-35.1709	-39.3360	0.3833	1,571

Table 8. Summary of the 2002 Seal Island acoustic survey results and SSB biomass estimate.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Seal Island	26-Aug	275	-54.768	0.012	27.50	-35.49	1,236	529
						Total SSB	1,236	

Table 9. Summary of the minimum observed spawning stock biomass for each of the surveyed spawning grounds in the Bay of Fundy/SW Nova component of the 4WX stock complex.

Location/Year	1997	1998	1999	2000	2001	2002
Scots Bay	160,168	72,473	40,972	106,316	163,900	141,000
Trinity Ledge	23,000	6,762	3,885	621	14,800	8,100
German Bank	370,400	440,704	460,823	356,372	190,500	393,121
Spectacle B						
- Spring	15,000	1,329	0	0	1,100	
- Fall					87,500	
Sub-Total	568,500	521,268	505,680	463,309	457,800	542,221
Seal Island					3,300	1,236
Browns Bank					45,800	
Total					506,900	543,457

Table 10. Summary of the 2002 Little Hope/Port Mouton acoustic survey results and SSB biomass estimates. Note the standard TS was corrected to account for a change in frequency from 50 kHz to 120 kHz. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Little Hope								
Survey	Sep 23	22.86	-44.14	0.15	-	-35.96	3,479	1,057
Fishing	Sep 24	0.77	-38.19	0.60	-	-35.96	461	321
Survey	Sep 26	0.42	-26.11	9.66	-	-35.96	4,193	718
Survey	Sep 29	0.35	-39.36	0.46	-	-35.96	160	
	Sep 29	4.30	-34.72	1.33	-	-35.96	5,723	4,213
	Sep 29	1.30	-42.22	0.24		-35.96	308	
	Sep 29	340	-52.62	0.02	-	-35.96	7,331	3,031
Survey	Oct 8	2.50	-25.99	9.92	-	-35.96	24,799	11,278
	Oct 8	5.64	-35.01	1.04	-	-35.96	5,841	1,602
	Oct 8	14.34	-37.71	0.67	-	-35.96	9,583	4,741
	Oct 8	250	-56.38	0.01	-	-35.96	2,270	1,056
						Total SSB	56,015t	

Table 11. Summary of the 2002 Eastern Passage acoustic survey results and mapping SSB biomass estimates.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Eastern Shore								
Fishing	Sept 13	0.40	-27.79	16.49	-	-35.96	6,595	3,734
Mapping	Sept 19	103	-	-			16,600	
Fishing	Sept 25	0.25	-21.49	27.99	-	-35.96	6,996	879
Survey	Oct 3	2.32	-25.66	10.71	-	-35.96	24,855	6,062
						Total SSB	41,455t	

Table 12. Summary of mapping survey undertaken in the vicinity of Glace Bay on the night of October 10, 2002. The survey covered two aggregations of spawning herring. The estimates were pooled for the SSB.

Location	Date	Area (m2)	Mean Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Glace Bay								
Mapping	Oct 10	40	-	-	-	-	7,700	-

Table 13. Summary of the 2003 winter acoustic surveys conducted off Chebucto Head, N.S. on the night of January 20.

Location	Date	Area (km2)	Weighted Sa (dB)/m2	Density (kg/m2)	Mean Length	Target Strength	Biomass (t)	Standard Error
Chebucto Head								
ME & PT	Jan 20	0.36	-32.06	2.21	24.91	-35.5	794	-

Table 14. Summary of the estimated biomass for locations outside the Bay of Fundy/Southwest Nova Scotia quota area. All areas except the Scotian Shelf are for individual spawning grounds and are estimates of SSB.

Area	1999	2000	2001	2002
Little Hope	14,600	5,200	21,300	56,015
Eastern Passage	9,500	10,870	16,700	41,455
Bras d'Or Lakes	-	70	-	-
Glace Bay	-	-	21,200	7,700
Scotian Shelf	22,300	85,600	145,000	-

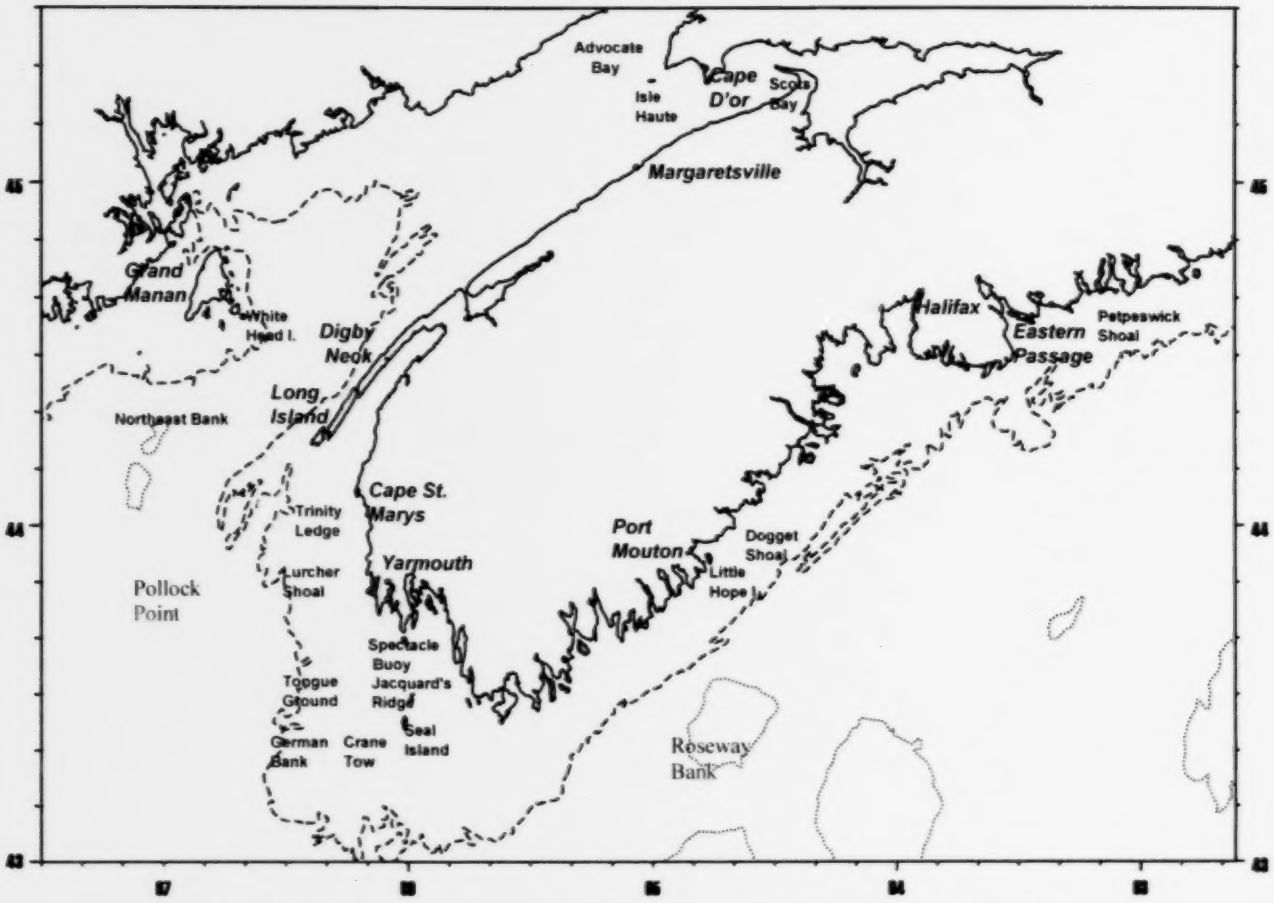

Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

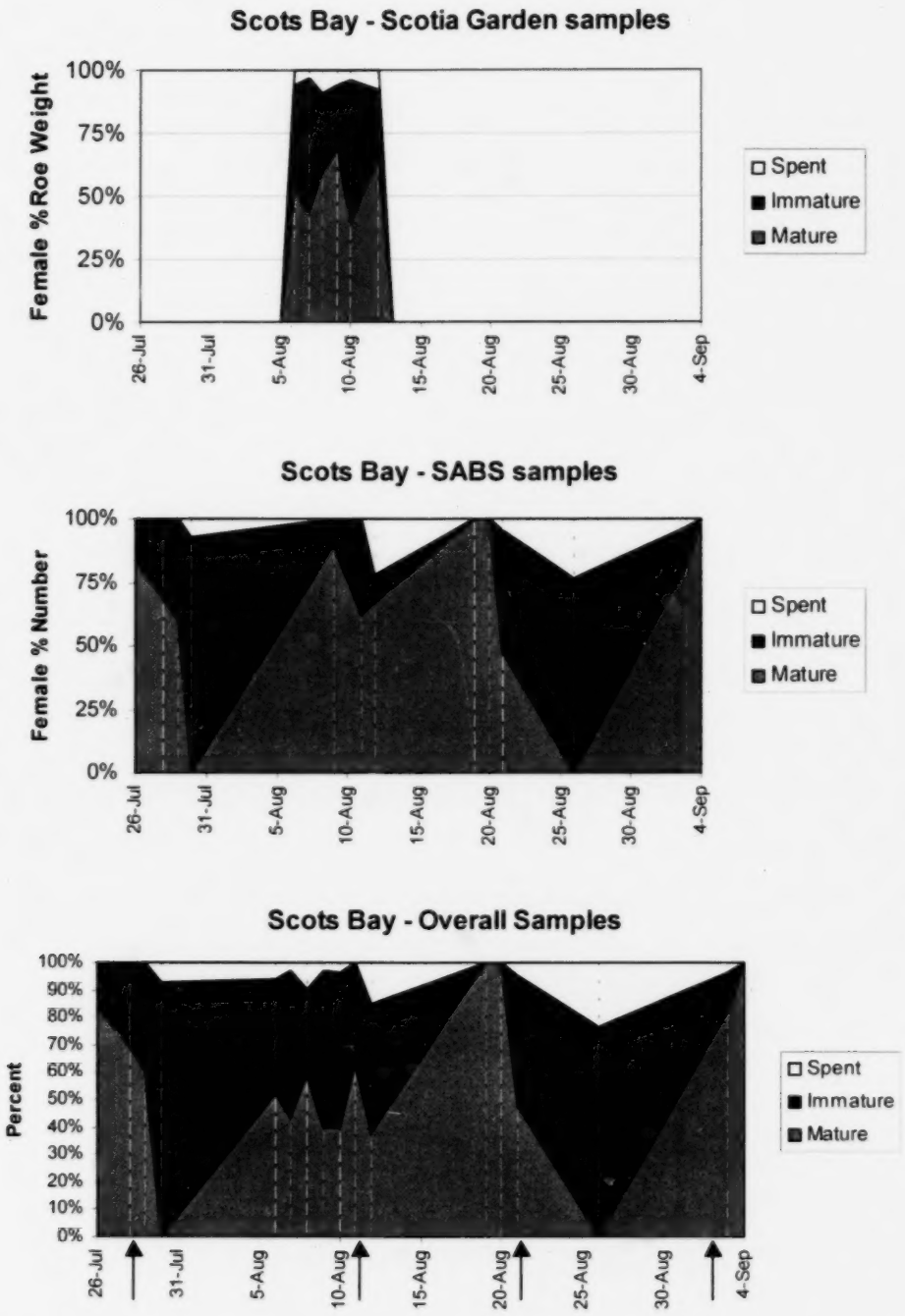

Figure 2. Daily herring female gonad maturity samples for Scots Bay in 2002. The dashed lines represent the actual sample points and arrows show the acoustic survey dates.

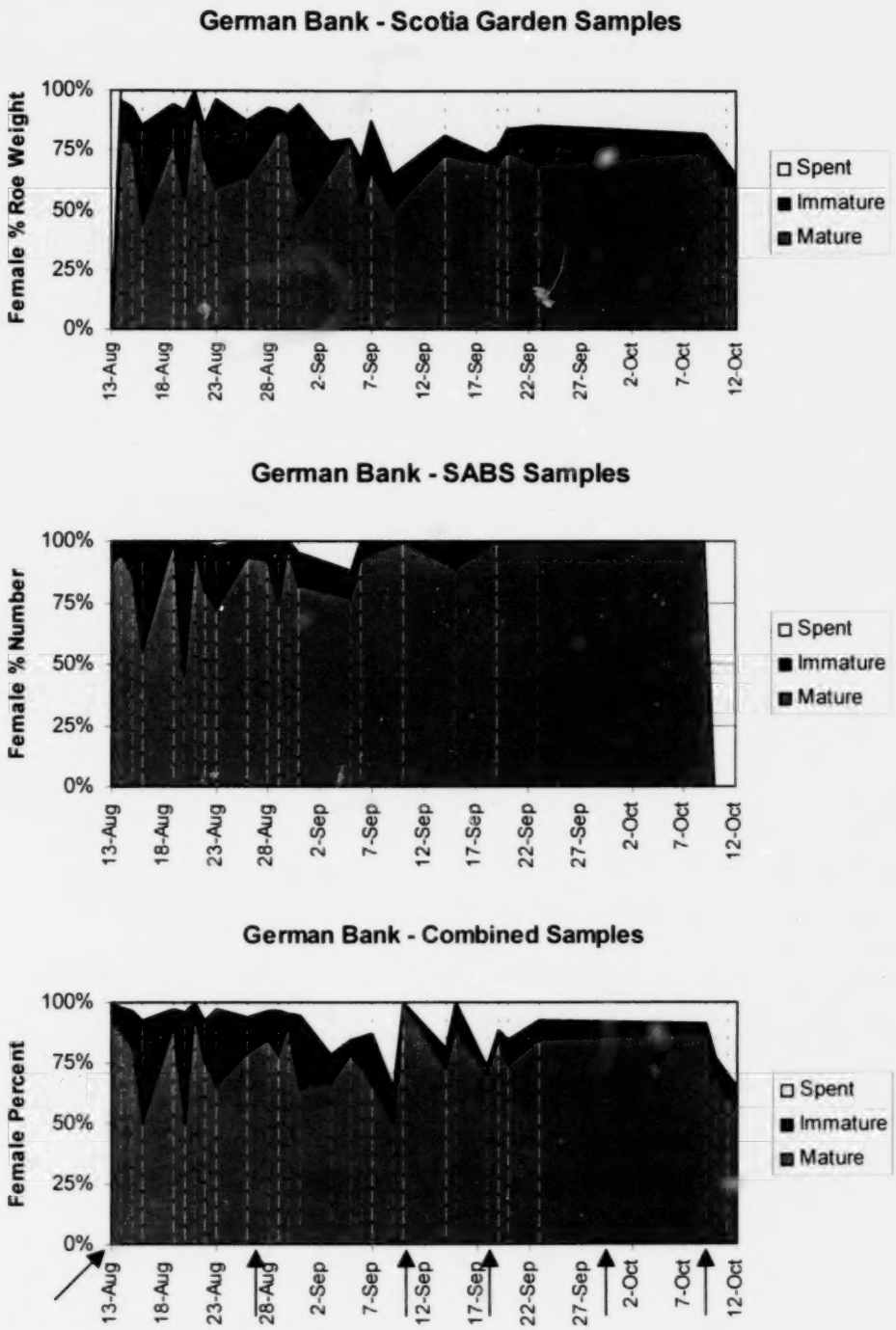

Figure 3. Daily herring female gonad maturity samples for German Bank in 2002. The dashed lines represent the actual sample points and arrows show the acoustic survey dates.

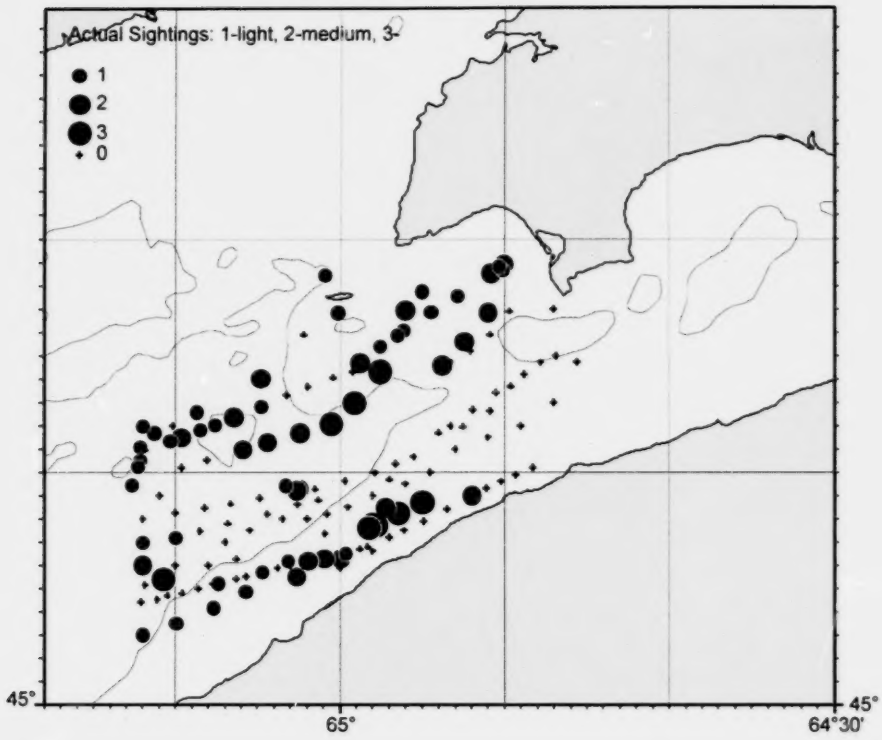

Figure 4. Summary of the Scots Bay July 28, 2002 spawning ground survey transects and the observed distribution of herring.

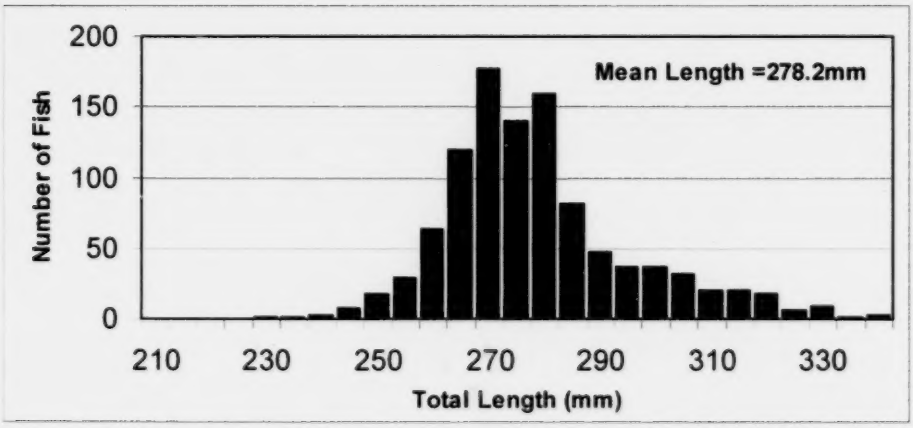

Figure 5. Length frequency of herring samples collected in Scots Bay on the nights of July 28/29, 2002.

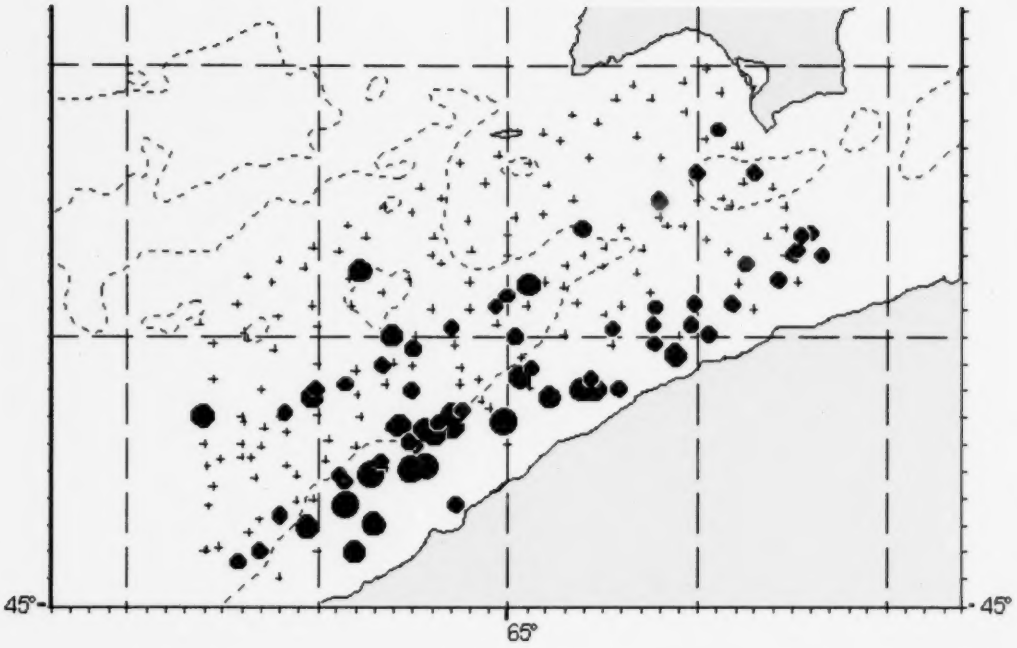

Figure 6. Summary of the Scots Bay August 11, 2002 spawning ground survey transects and the observed distribution of herring. Data for both recording and non-recording vessels are presented.

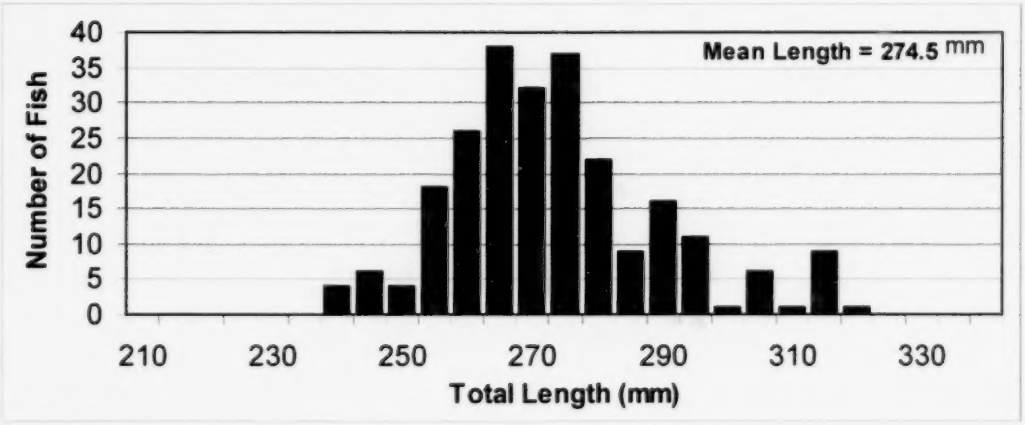

Figure 7. Length frequency of herring samples collected in Scots Bay on the nights of August 11/12, 2002.

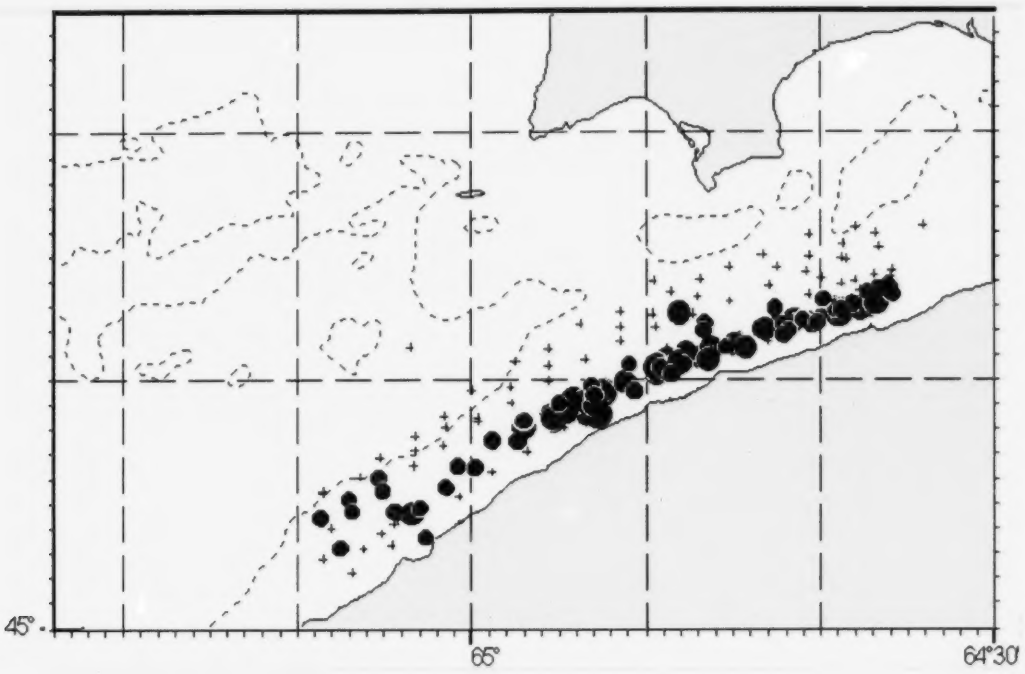

Figure 8. Summary of the Scots Bay August 21, 2002 spawning ground survey transects and the observed distribution of herring. Data for both recording and non-recording vessels are presented.

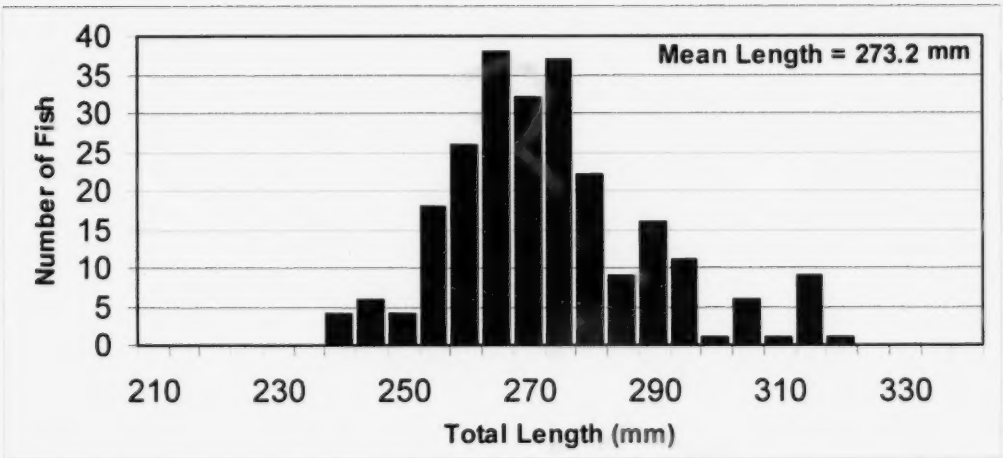

Figure 9. Length frequency of herring samples collected in Scots Bay on the nights of August 21/22, 2002.

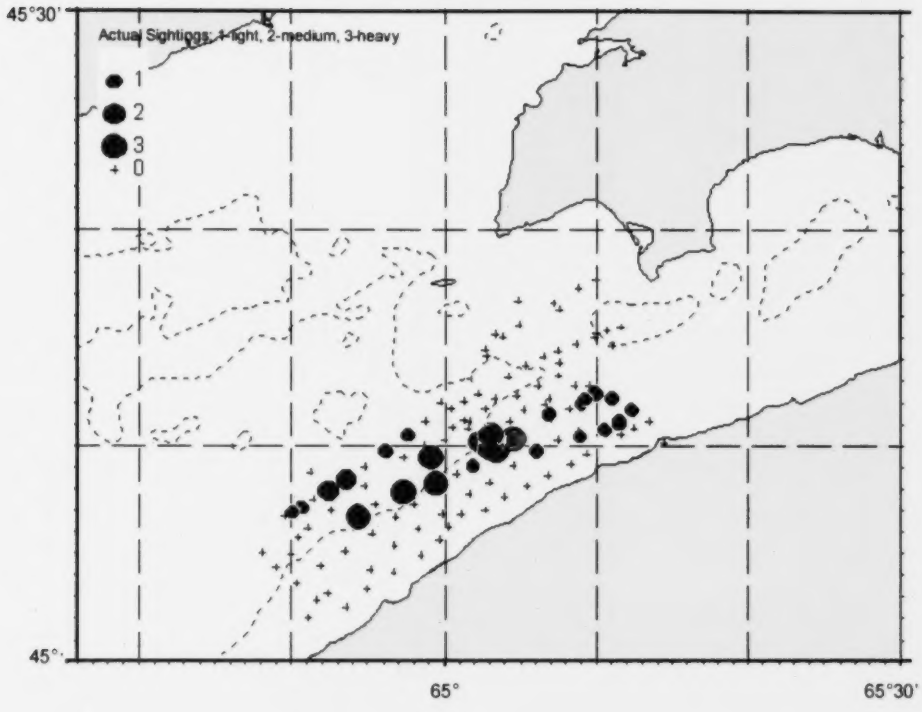

Figure 10. Summary of the Scots Bay September 2, 2002 spawning ground survey transects and the observed distribution of herring. Data for both recording and non-recording vessels are presented.

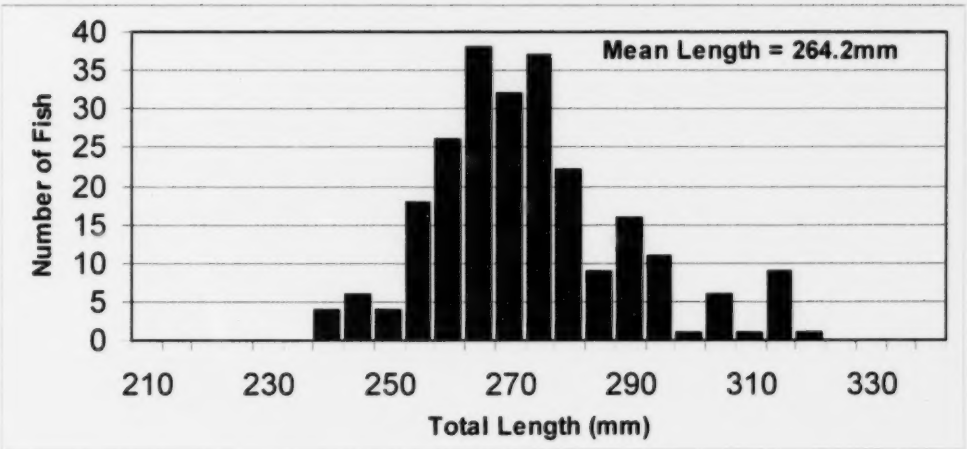

Figure 11. Length frequency of herring samples collected in Scots Bay on the nights of September 2/3, 2002.

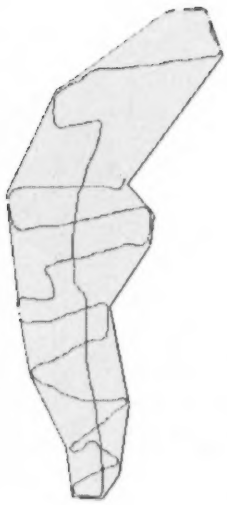

Figure 12. Vessel track of the Attiboy September 2. 2002 on Trinity ledge . Total area of coverage was 0.47 km^2.

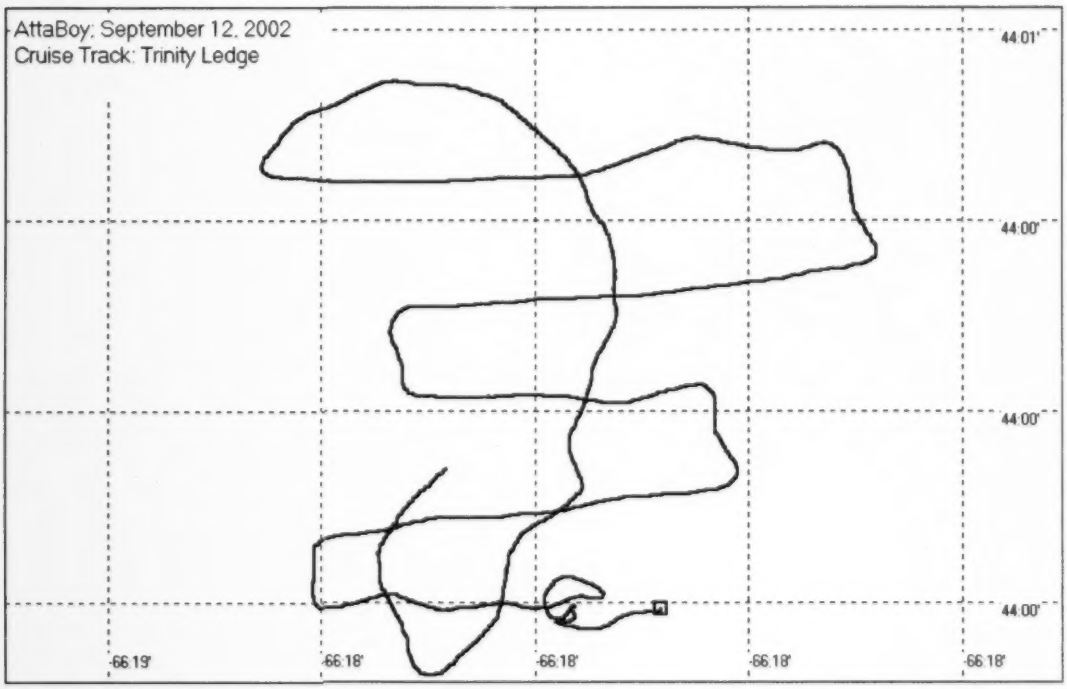

Figure 13. Vessel track of the "Attiboy" September 19, 2002 on Trinity ledge . Total area of coverage was 0.60 km^2.

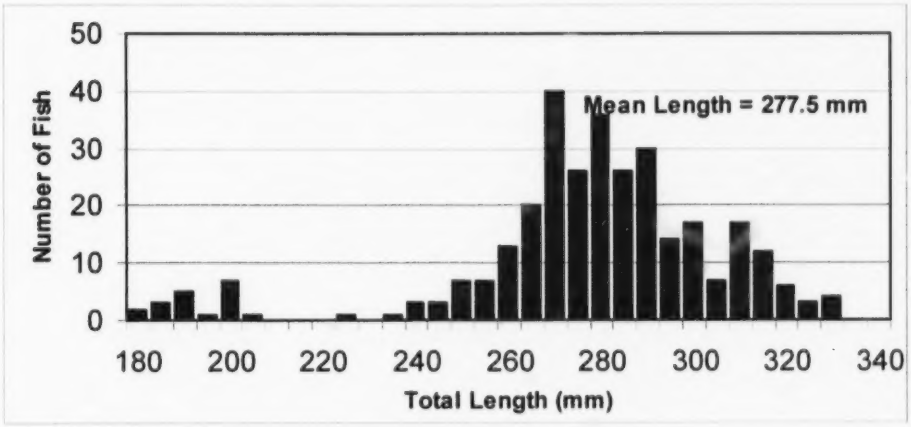

Figure 14. Length frequency of herring samples collected from German Bank on the nights of August 11, 2002.

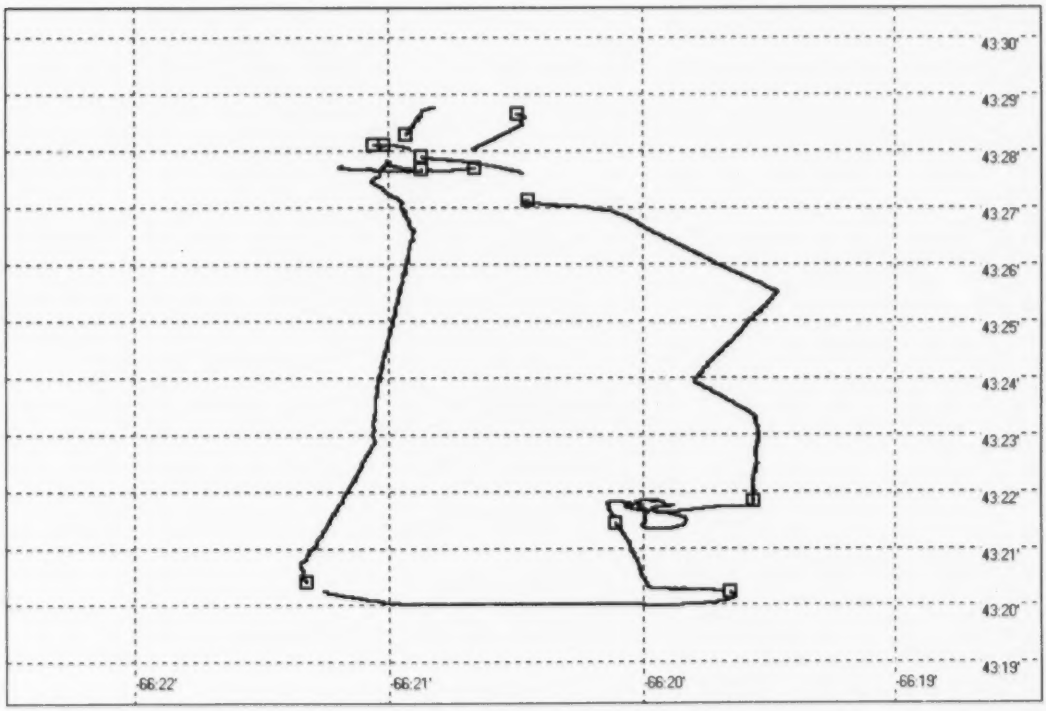

Figure 15. Vessel track of the Island Pride from German Bank on August 11, 2002. Total area of coverage was 31.0 km^2.

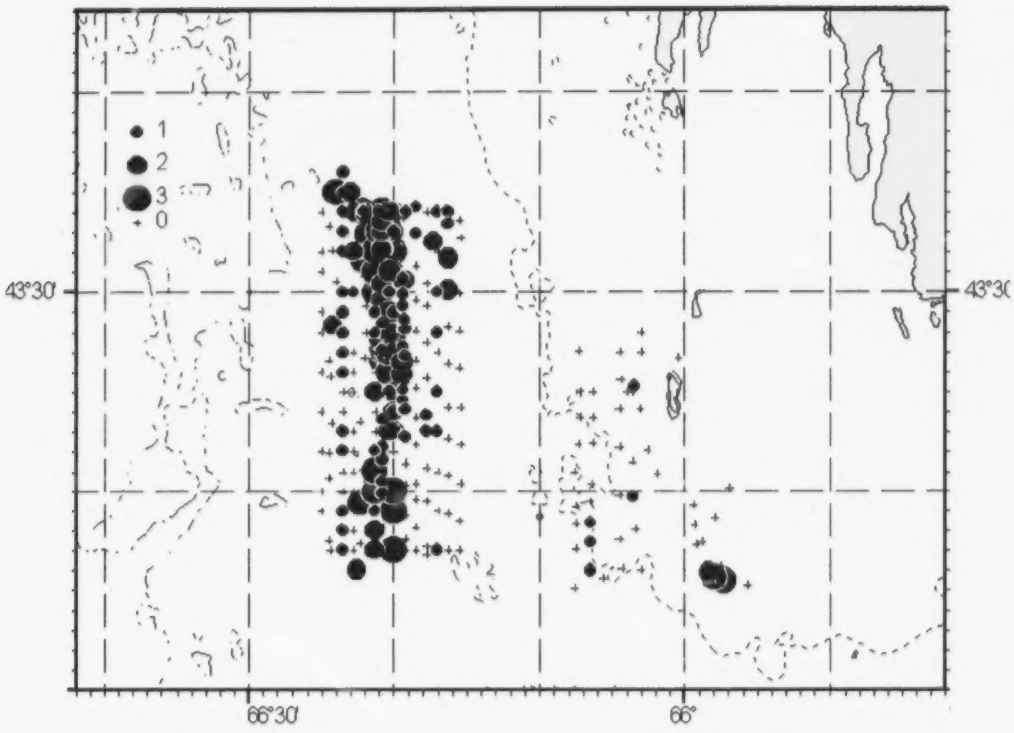

Figure 16. Distribution of herring during the August 26, 2002 survey of the German Bank and Seal Island spawning grounds. Area surveyed was 450km^2 on German Bank and 140 km^2 around Seal Island.

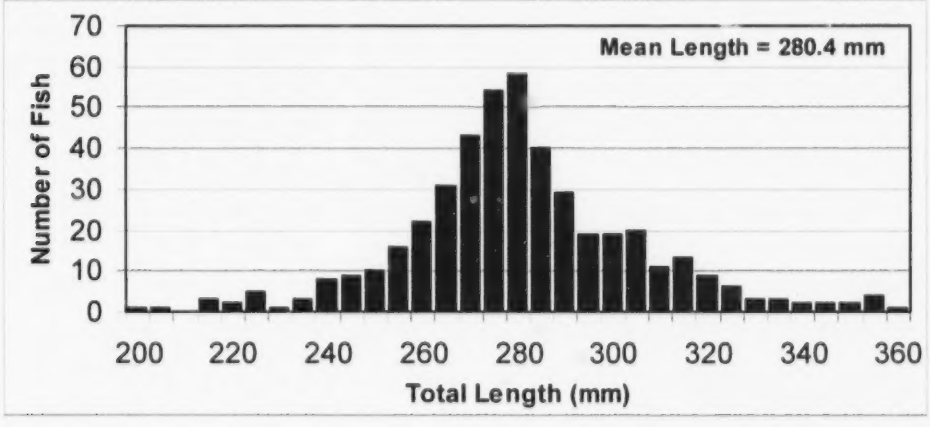

Figure 17. Length frequency distribution of herring sampled from purse seine catches on German Bank on August 26, 2002.

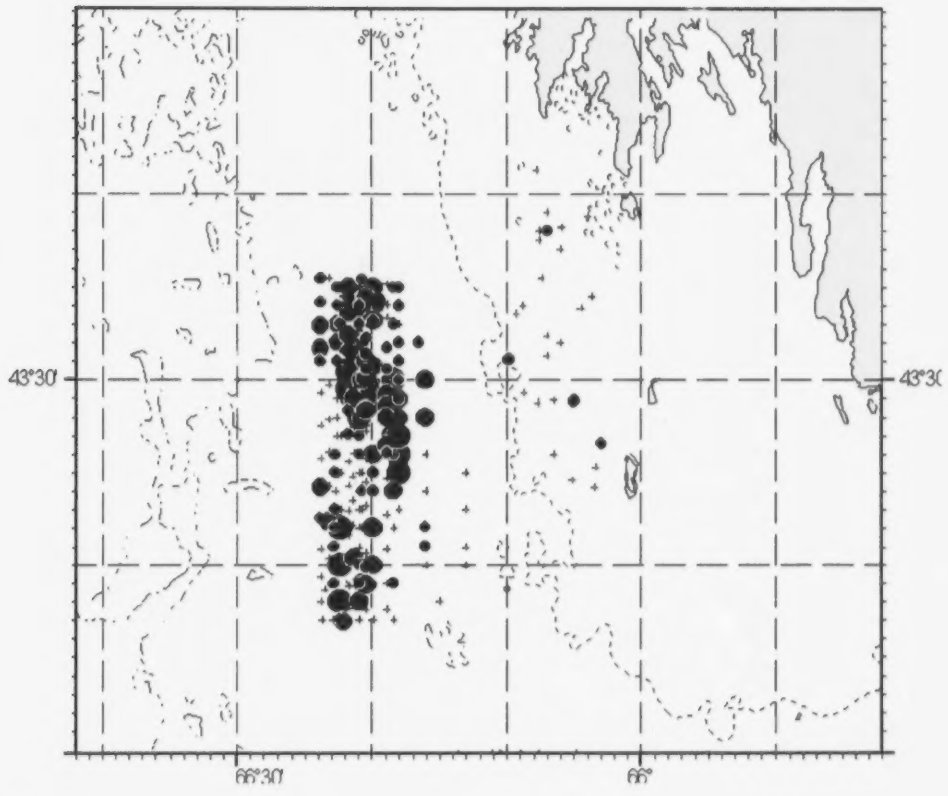

Figure 18. Distribution of herring during the September 10, 2002 survey of the German Bank. The few fish observed around Seal Island were not quantified.

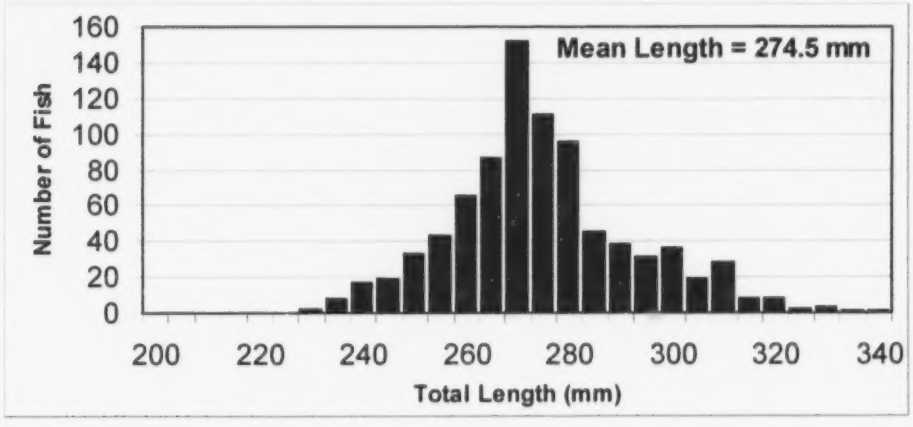

Figure 19. Length frequency distribution of herring sampled from purse seine catches on German Bank on September 10, 2002.

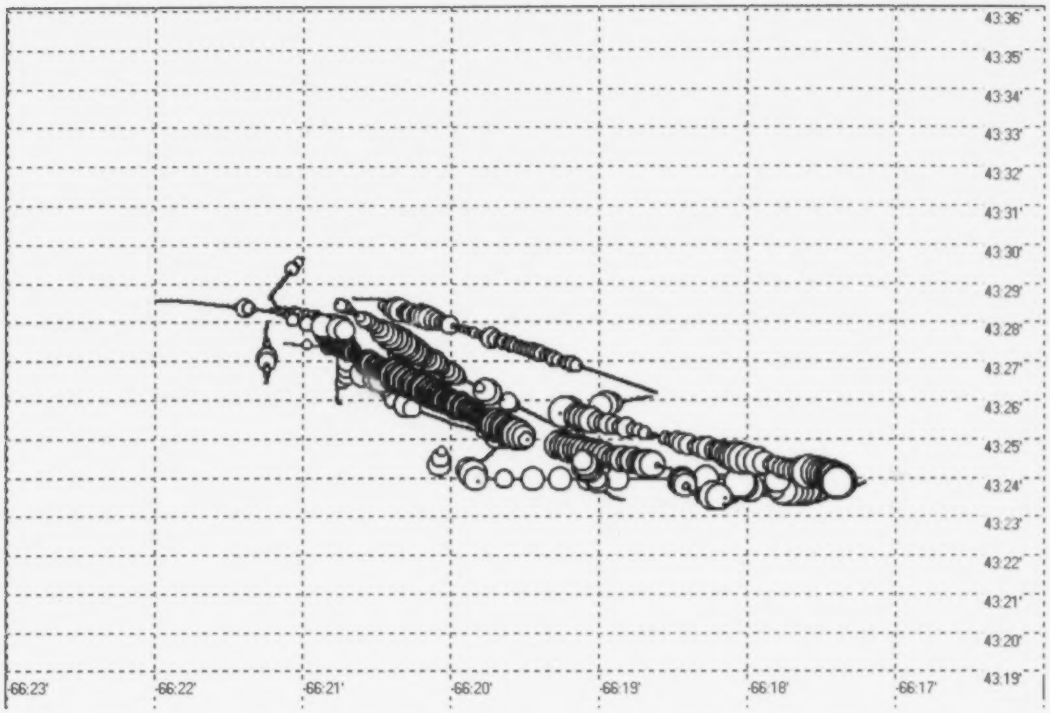

Figure 20. Vessel track and distribution of herring observed on September 19, 2002 by two recording vessels on the German Bank spawning grounds. The school area was 35.0 km^2.

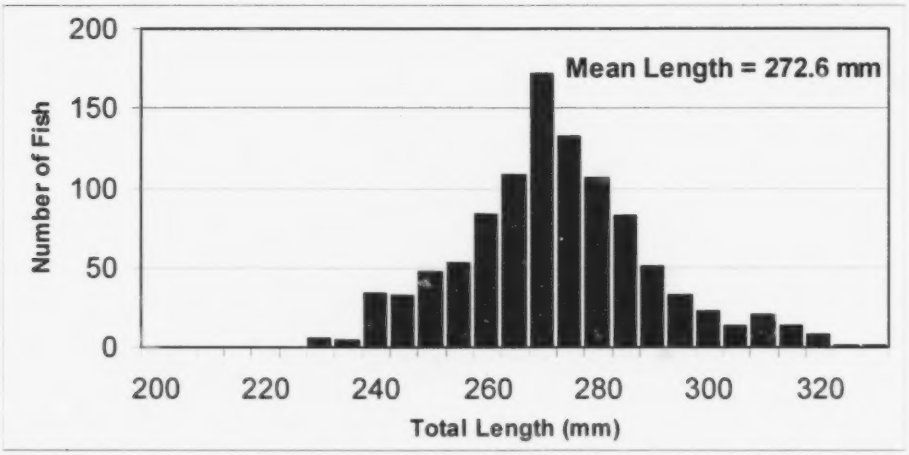

Figure 21. Length frequency distribution of herring sampled from purse seine catches from German Bank on September 19, 2002.

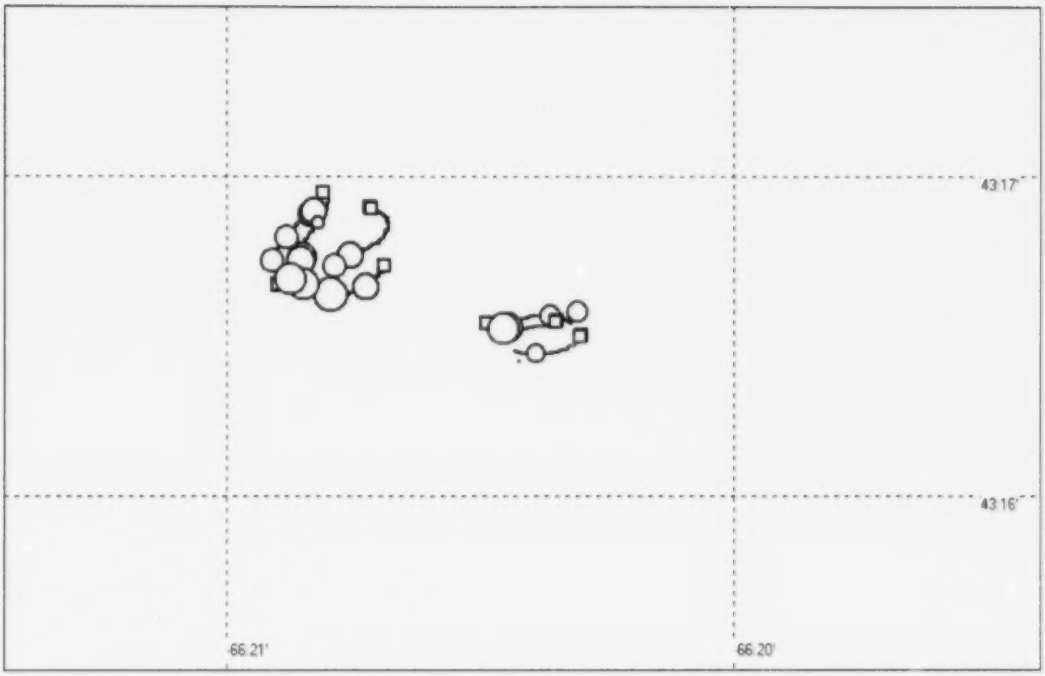

Figure 22. Distribution of herring during the September 29, 2002 fishing night on the German Bank spawning grounds. Total area surveyed was 0.40km^2.

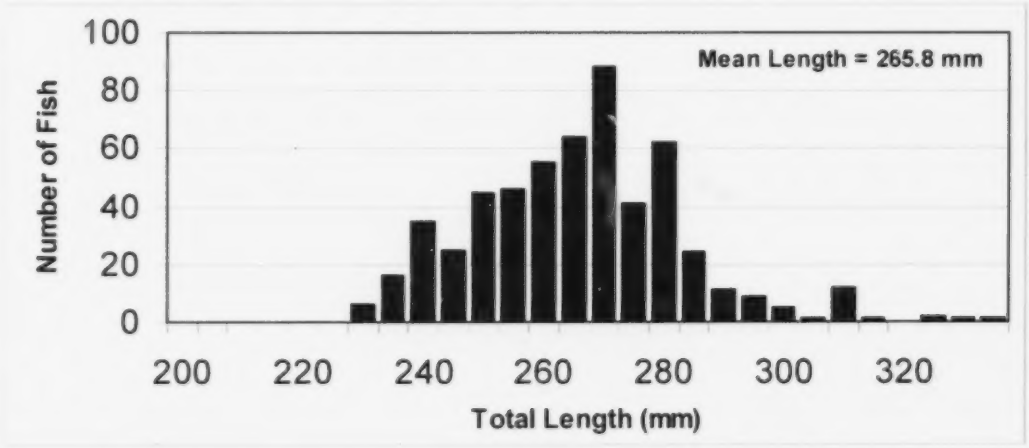

Figure 23. Length frequency distribution of herring sampled from purse seine catches from German Bank on September 13, 2001. The mean length of fish was 26.86cm.

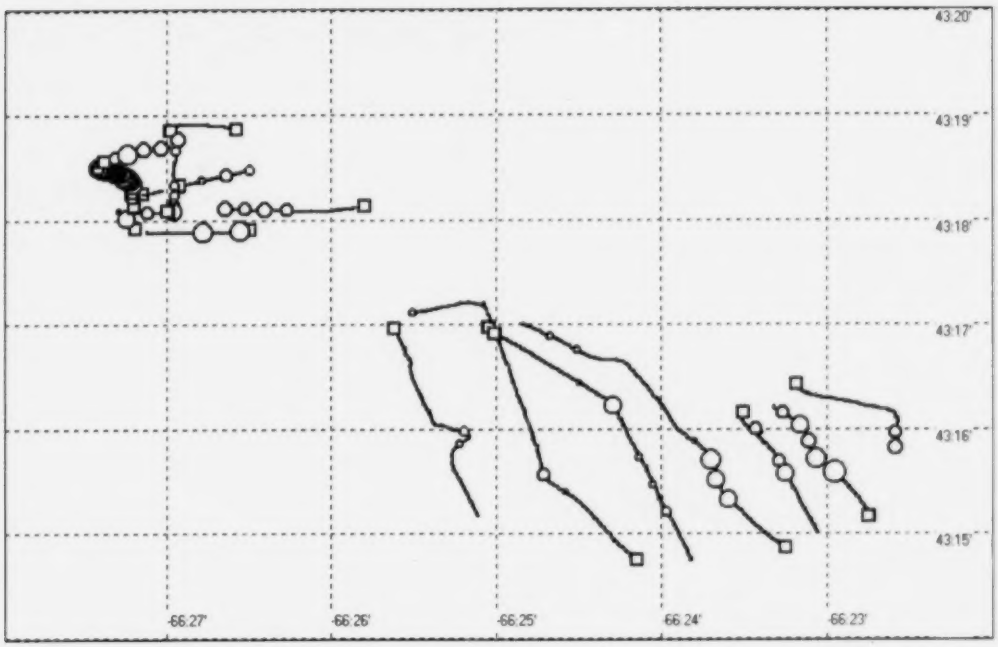

Figure 24. Distribution of herring during the October 8, 2001 fishing night on the German Bank spawning grounds. Area surveyed equals 14.0km^2.

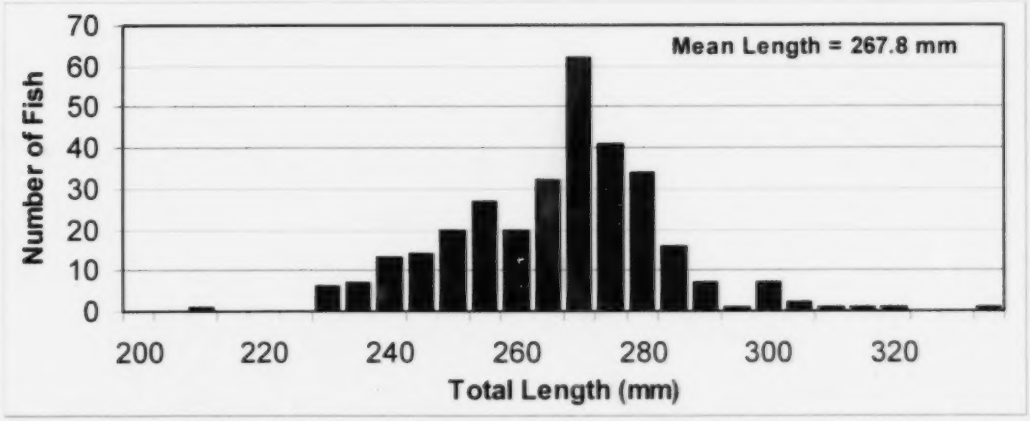

Figure 25. Length frequency distribution of herring sampled from purse seine catches from German Bank on October 8, 2002.

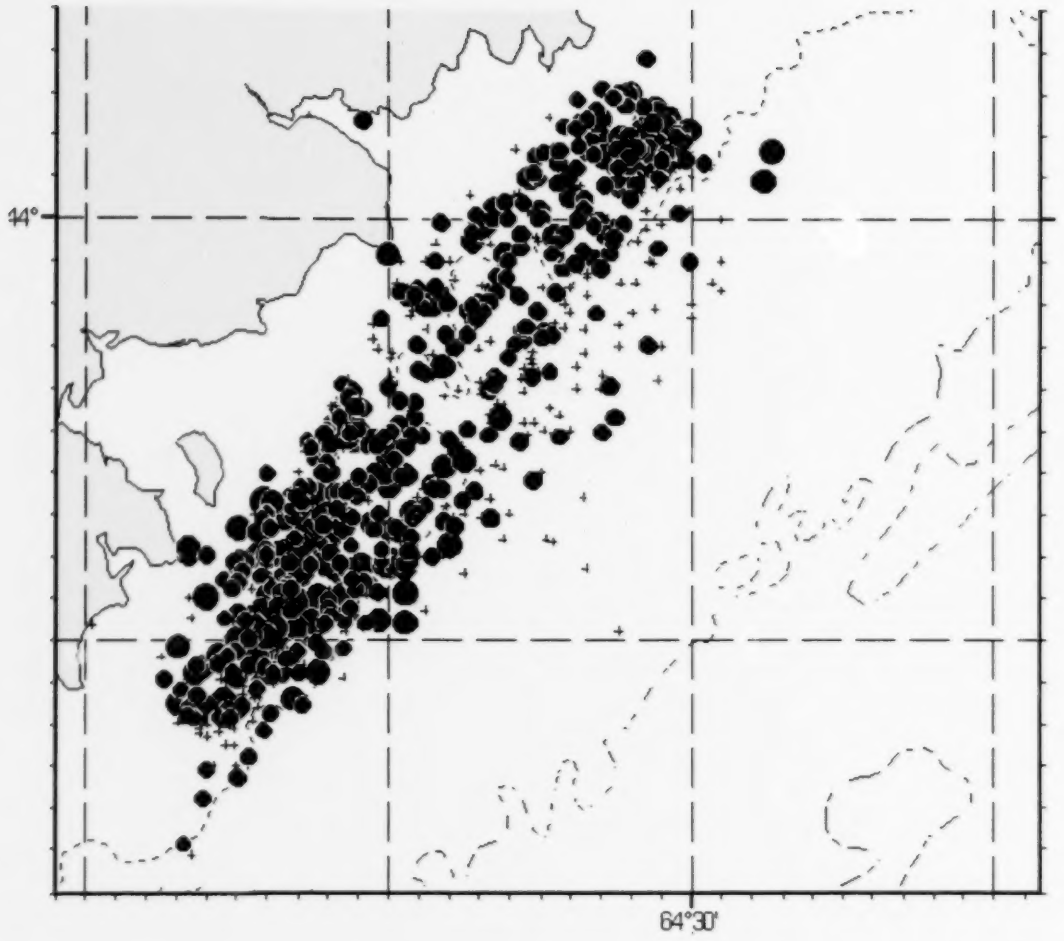

Figure 26. Survey coverage and the distribution of herring during the September 29, 2002 survey of the Little Hope Port Mouton spawning grounds.

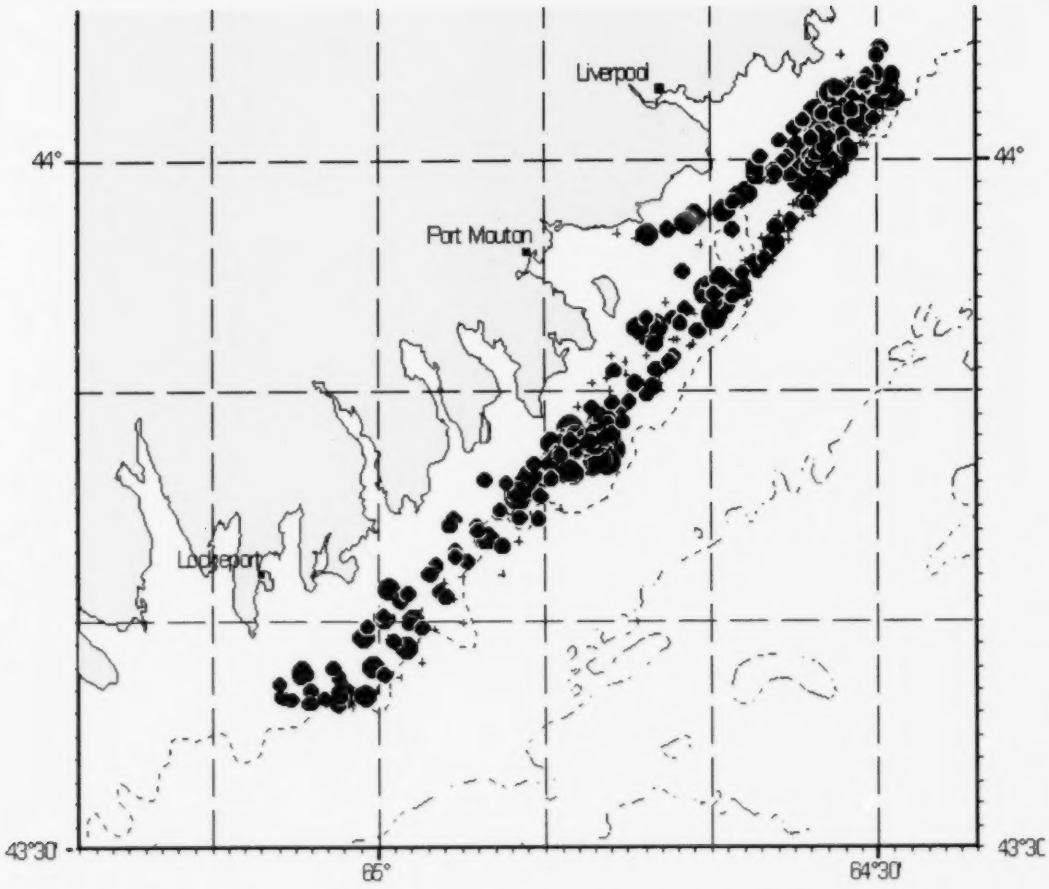

Figure 27. Survey coverage and the distribution of herring during the October 8, 2002 survey of the Little Hope Port Mouton spawning grounds.

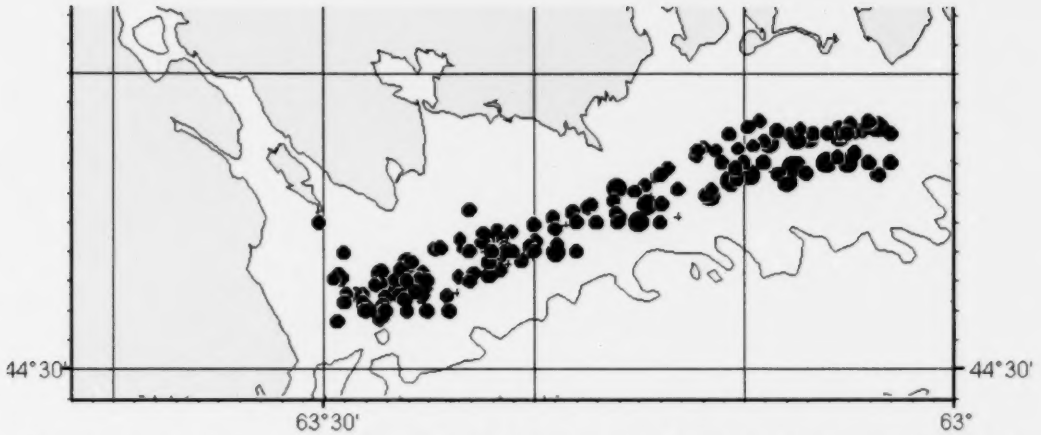

Figure 28. Survey coverage and the distribution of herring during the September 19, 2002 survey of the Eastern Passage spawning area.

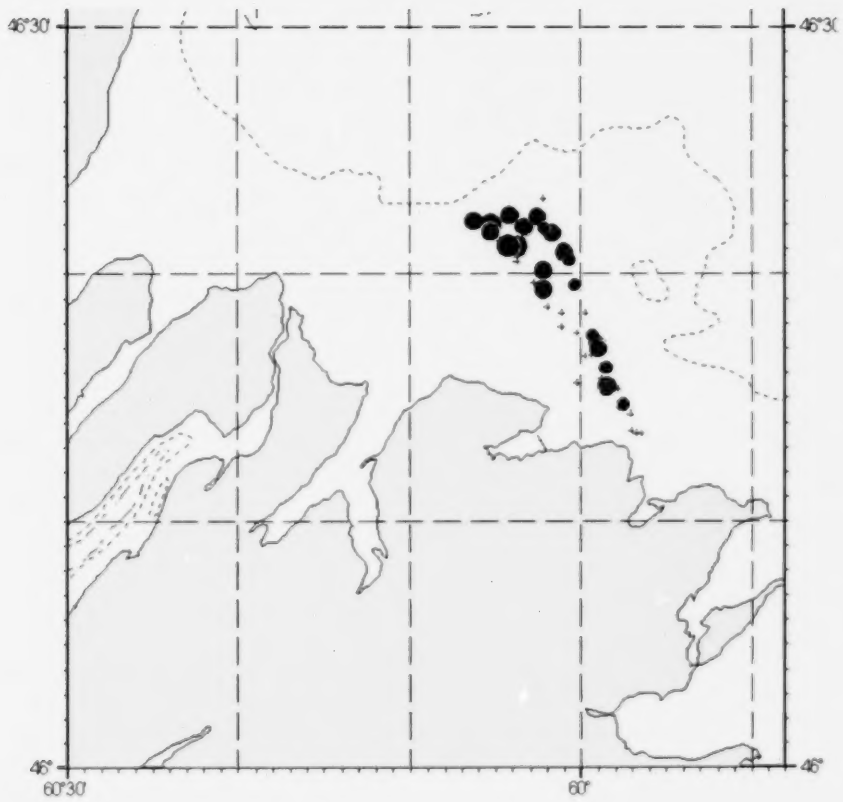

Figure 29. Survey coverage and the distribution of herring during the October 10, 2002 survey of the Glace Bay spawning grounds.

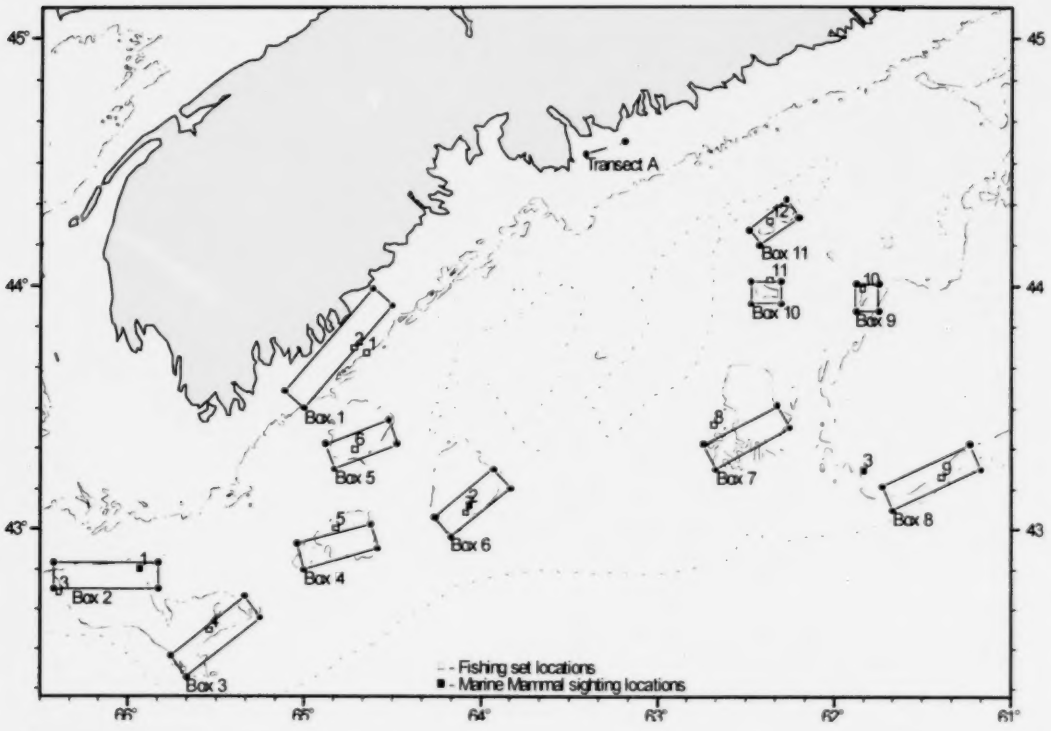

Figure 30. Survey boxes, fishing set locations, and marine mammal sightings locations for the Alfred Needler herring acoustic survey from October 22 to November 2, 2002.

Appendix A

The following provides a general description of the types of surveys, survey protocol and the analytical procedure used to estimate biomass from the acoustic data collected by scientific and commercial fishing vessels. Prior to 1999, surveys were undertaken on an *ad hoc* basis and usually at the request of the fishing industry. This resulted in some uncertainty as to the turnover time between spawning waves and the potential for double counting of fish. In 1998 a procedure was established to estimate the percent of herring remaining on the spawning ground between surveys when the time between surveys was less than 10 days (Melvin et. al., 1999). To avoid potential problems associated with an elapsed time of less than 10 days between surveys, a survey schedule was established for the main spawning area at approximately two-week intervals for 1999, 2000 and 2001. Additional research was undertaken in 2001 to investigate turnover time on German Bank (Power et al., 2002)

Surveys:

Surveys undertaken by the fishing industry fall into two broad categories – mapping surveys which do not involve quantitative acoustic data, and quantitative surveys which depend heavily on acoustic data to estimate biomass. Most scheduled surveys involve a combination of both types.

Mapping Surveys:

In 2001, surveys that relied solely on the mapping approach, used in the early years of industry based surveying, were few. Most surveys included a combination of both mapping and acoustic data collection. Mapping data (log sheets) were collected on each survey by all vessels participating in the survey to establish the outer bounds and distribution of herring in the survey area. Biomass estimates were also made from the mapping type data to provide a quick approximation of fish numbers and to use as input for the "survey, assess, then fish" protocol when uncertainty prevailed. The procedure involved recording information on fish abundance and distribution observed from the sounders and sonars of vessels without acoustic recording systems. Survey protocol required that parallel transects were run with vessel spacing varying from 1/8 mile to ½ mile, depending on the availability of sonar, to ensure that no large schools were missed. Observations were recorded every 5 to 10 min on standardized data sheets. The observations were later categorized into the 3 density values (light, medium or heavy) and biomass estimated using the area and a relative density category (Table 1A) (Melvin *et. al*, 2000; Stephenson *et. al*, 1998). In most of the 2001 surveys at least one automated acoustic system was available to collect quantitative data.

Mapping data were contoured and plotted using the ACON Data Visualization package and the triangular contour method (Black, 2000). Blanking distance was set to the maximum distance between valid data recordings and varied between 1 and 3 miles depending on the survey. Interpolation between data points was undertaken using the inverse distance weighting gradient approach to compute the density at any given point. Once the area of the three contour levels was estimated, the areas (km^2) were multiplied by the appropriate fish density in accordance with the previously defined scale and summed to get the total biomass within the survey coverage area. However, final biomass estimates were based on acoustic density estimates whenever available.

Quantitative Surveys:

Industry based structured surveys were used throughout the 2001 spawning season to document the distribution and abundance of herring on individual spawning grounds. Standard operating procedure for surveying involved the presence of DFO scientific staff onboard one or more of the vessels to direct the activities, assign transects, determine coverage (with fishing captains), sample fish and download/collect the data upon completion of the survey. In 2001 most of the data were downloaded by an industry (Herring Science Council) technician. Typically, a series of randomly selected transects were provided to the participating vessels for the area of interest and a two-phase survey design (i.e. search then survey) implemented. The initial phase involved the search for fish on the spawning grounds along the pre-defined transects using vessels equipped with and without acoustic logging systems. Fishing vessels without a recording system would document their observations as if they were undertaking a mapping survey. Once the entire area was covered and the distribution of fish identified, each vessel involved in the survey was assigned a series of transects to execute in the area containing the higher concentration of fish. Biomass estimates were made using the procedure described below for fishing operations, except that transects were usually of similar length and selected at random within the pre-defined area of interest. Transect estimates were weighted for length (i.e. distance traveled) and the mean transect backscatter (converted to kg/m^2 using the Foote equation) extrapolated for the survey area to estimate the minimum observed biomass.

Analytical Procedures:

The computational procedures for analyzing data collected from standard fishing operations and structured surveys are similar. However, given that the vessel track from standard fishing operations does not follow any standardized survey design, some assumptions have to be made about the area covered and the representative nature of the data. Unfortunately, there are some recording nights when the data are simply too convoluted or too sparse relative to the area covered or the area covered is too small to be incorporated into the SSB for the stock. In

recent years fishing captains have attempted to structure their ad hoc recordings by running parallel lines when documenting aggregations of fish as recommended (Melvin and Power, 1999). Furthermore, when the area covered in search of fish is of sufficient size and representative lines (equivalent to transects) can be extracted, an estimate of observed biomass can be obtained.

For structured surveys, transects are usually predefined and represent randomly distributed parallel lines within the survey area. Transects for fishing operations are extracted from the vessel track by dividing the track into a series of non-intersecting segments. Portions of the vessel track where the vessel looped back to take a second look at a group of fish are always removed to prevent over-weighting of areas of heavy fish concentrations.

Fish biomass is estimated by selecting segments of the vessel's track (transects), computing the distance weighted average area backscatter (Sa), estimating the mean weight of fish/m^2 under the vessel using the Foote target strength equation (Foote, 1987) and multiplying by the area covered. Target strength estimates are based on herring length frequency samples and associated weights collected from several commercial vessels fishing in the area of interest as follows:

$$TS \text{ (target strength)} = (20 \text{ Log(length)} - 71.9) - 10 \text{ Log(weight)} \quad \text{in dB kg}^{-1}.$$

Length frequency data are normally obtained from the survey vessel or vessels fishing in the survey area for TS calculation and target verification. The weight component of the TS equation is computed from recent data on the weight/length relationship for the mean size of fish observed. In the event length frequency data are unavailable, a standard TS of –35.5 is used for calculating biomass. Such events occur when gillnet samples are collected (selective for larger size) or no fishing is undertaken. The standard target strength corresponds to the TS of a 28.0cm herring in September. This represents the lower end of the observed mean spawning lengths and generally translates into smaller biomass estimate.

The area backscattering coefficient (Sa) is initially computed by averaging the return signal for a specific navigational interval (usually 20 navigational fixes) along the transect and weighted by the distance traveled during that interval. The average Sa values, weighted for distance, are then used to compute the mean Sa (dB m^{-2}) for the transect. Average biomass density per transect (sample unit) was computed from the estimated Sa and TS as follows:

$$\text{Biomass density/transect} = 10^{(\text{mean Sa - Target strength})/10} \quad \text{in kg m}^{-2}$$

The area covered by the vessel is determined by fitting a rectangle or polygon over the vessel tracks and estimating the area. When available, sonar data are used to determine the boundaries of the fish schools. The area is then multiplied by the biomass density/stratum to determine the biomass in the area covered by the fishing vessel. Standard Error (S.E.) is estimated from the standard deviation of

the transect biomass density, where n is the number of transects. The area of coverage is then multiplied by standard error to determine the SE of the overall biomass estimate.

Table A1. Summary of weightings for each category used in mapping surveys. The tonnes/set is based on the fishermen's estimate of their catch if they set on the school of fish, converted to km^2. The acoustic values are the range of tonnages estimated from acoustic recordings and categorized by the observers.

Category	Tonnes/Set	Tonnes/km^2	Acoustic (tonnes/km^2)
No Fish	0	0	0
Light	5	200	230 - 250
	10	400	
Moderate	25	1000	600 - 1300
	50	2,000	
Heavy	100	4,000	2,000 – 11,000
	200	8,000	
	250	10,000	
	500	21,000	